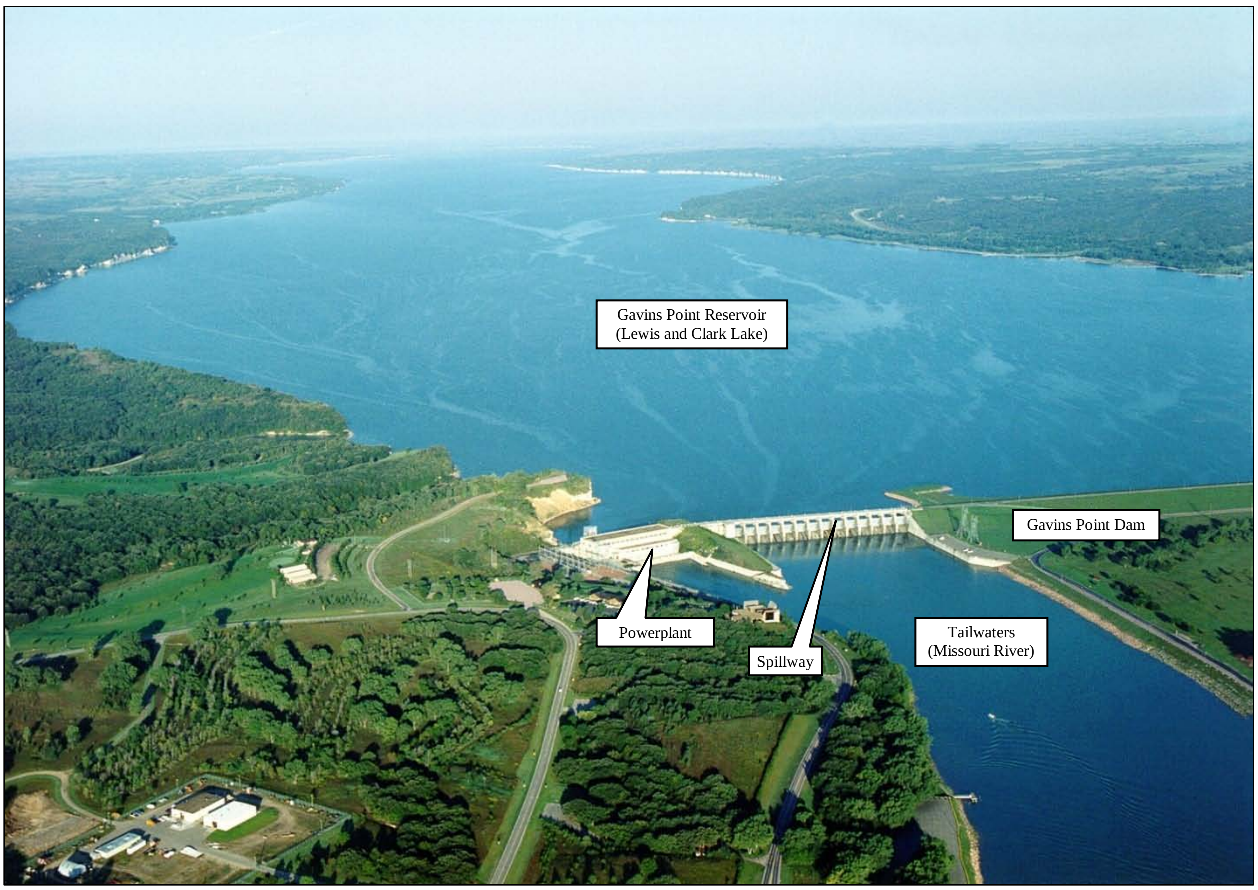
Water Quality Special Study Report

U.S. Army Corps of Engineers
Omaha District

Water Quality Conditions Monitored at the Corps' Gavins Point Project in Nebraska/South Dakota during the 3-Year Period 2008 through 2010



Aerial Photo of Gavins Point Dam, Tailwaters and Reservoir

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(Report Number: CENWO-ED-HA/WQSS/GavinsPoint/2011)

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November 2011

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EXECUTIVE SUMMARY

The U.S. Army Corps of Engineers (Corps) Gavins Point Project consists of Gavins Point Dam and Gavins Point Reservoir (i.e., Lewis and Clark Lake). Gavins Point Dam is located on the Missouri River at River Mile (RM) 811 along the Nebraska/South Dakota border, near the town of Yankton, South Dakota. The reservoir and dam are authorized for the uses of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. Lewis and Clark Lake is an important recreational resource to both the States of Nebraska and South Dakota.

Water quality monitoring was conducted at the Gavins Point Project by the Omaha District (District) over the 3-year period of 2008 through 2010. The water quality monitoring conducted included: 1) continuing long-term, fixed-station monitoring in Lewis and Clark Lake at a near-dam deepwater location and of the Gavins Point Dam tailwaters; 2) monthly sampling and continuous monitoring (i.e., hourly) of water quality conditions in the powerplant of water discharged through Gavins Point Dam; 3) intensive water quality surveys in 2008, 2009, and 2010; 4) bacteria monitoring; and 5) a special study in 2008. The results of this monitoring were used to assess the existing water quality conditions at the Gavins Point Project.

Water quality conditions in Lewis and Clark Lake vary temporally, longitudinally (from the dam to the reservoir's upstream reaches), and vertically (from the reservoir's surface to the bottom). During periods of calm weather in the summer, Lewis and Clark Lake develops a slight thermal stratification. When this slight stratification occurs, a thermocline is present at about 8 meters depth. This indicates the reservoir is probably polymixic. The thermal stratification breaks down under windier conditions, given the shallow depth of the reservoir (i.e., 14 meters), and the reservoir mixes throughout its water column. Parameters that significantly varied from the surface to the bottom of the reservoir at the near-dam, deepwater location included water temperature, dissolved oxygen, ORP, pH, alkalinity, total organic carbon, total ammonia, and total phosphorus. The phytoplankton community of Lewis and Clark Lake was dominated by diatoms. The zooplankton community in Lewis and Clark Lake was dominated by Cladocerans and Copepods. Monitoring indicated that the lacustrine zone of Lewis and Clark Lake is currently in a eutrophic state.

Water quality monitoring of the existing conditions of Lewis and Clark Lake indicated a possible water quality concern regarding nutrients. The Nebraska "nutrient criteria" for total phosphorus and chlorophyll *a* applicable to Lewis and Clark Lake were regularly exceeded throughout the reservoir and exceed Section 303(d) impairment criteria identified by the State of Nebraska for the protection of aquatic life. It is also noted that the estimated loss of 24.3 percent of the multi-purpose pool volume of Lewis and Clark Lake is approaching Nebraska's impairment identification criterion of 25 percent volume loss.

Water quality monitoring of the existing conditions of the Missouri River downstream of Gavins Point Dam discharge did not indicate any water quality concerns. There appeared to be little correlation between dam discharge rates and measured water temperature and dissolved oxygen concentrations. Inflow temperatures of the Missouri River to Lewis and Clark Lake tend to be at little cooler than the outflow temperatures of Gavins Point Dam during the spring and early summer. Outflow temperatures of the Gavins Point Dam discharge tend to be a little cooler than the Missouri River inflow temperatures in the late-summer and fall.

The Omaha District is planning to pursue the application of the Corps' CE-QUAL-W2 hydrodynamic and water quality model to Lewis and Clark Lake. CE-QUAL-W2 is a powerful tool to aid in addressing reservoir water quality management issues. Application of the CE-QUAL-W2 model will allow the Corps to better understand how the operation of the Gavins Point Project affects the water quality in Lewis and Clark Lake and the dam discharges to the Missouri River. It is almost a certainty that water quality issues at the Gavins Point Project will remain important in the future.

1 INTRODUCTION

1.1 RECENT WATER QUALITY MONITORING AT THE CORPS' GAVINS POINT PROJECT

Water quality monitoring conducted by the Omaha District (District) at the Gavins Point Project over the 3-year period 2008 through 2010 included: 1) continuing long-term, fixed-station monitoring in Lewis and Clark Lake at a near-dam deepwater location and of the Gavins Point Dam tailwaters; 2) monthly sampling and continuous monitoring (i.e., hourly) of water quality conditions in the powerplant of water discharged through Gavins Point Dam; 3) intensive water quality surveys in 2008, 2009, and 2010; 4) bacteria monitoring; and 5) a special study in 2008. The continuing long-term, fixed-station monitoring consisted of monthly field measurements and sample collection. The monitoring in the Gavins Point powerplant was on water drawn from the Unit waterways prior to passing through the dam's turbines. The intensive surveys included monitoring at four additional in-reservoir sites and monitoring of the Missouri River inflow to the reservoir. The Niobrara River inflow to the Missouri River was also monitored. Bacteria monitoring at five beach areas was conducted weekly from May through September. The special study conducted in 2008 was to evaluate potential water quality impacts from the construction of Emergent Sandbar Habitat in the headwaters of Lewis and Clark Lake. This report presents the findings of the water quality monitoring conducted by the District at the Gavins Point Project during the 3-year period 2008 though 2010.

1.2 MISSOURI RIVER MAINSTEM SYSTEM

The Gavins Point Project is part of the Missouri River Mainstem System (Mainstem System). The Mainstem System is comprised of six dams and reservoirs constructed by the U.S. Army Corps of Engineers (Corps) on the Missouri River and the free-flowing Missouri River downstream of the project dams. The six reservoirs impounded by the dams contain about 73.3 million acre-feet (MAF) of storage capacity and, at normal pool, an aggregate water surface area of about 1 million acres. The six dams and reservoirs in an upstream to downstream order are: Fort Peck Dam and Reservoir (Montana), Garrison Dam and Reservoir (North Dakota), Oahe Dam (South Dakota) and Oahe Reservoir (North and South Dakota), Big Bend Dam and Reservoir (South Dakota), Fort Randall Dam and Reservoir (South Dakota), and Gavins Point Dam and Reservoir (Nebraska and South Dakota). The water in storage at the all Mainstem System reservoirs at the end of 2010 (i.e., December 31, 2010) was 57.03 MAF, which is about 78 percent of the total system storage volume. Drought conditions in the upper Missouri River Basin prior to 2008 had reduced the water stored in the Mainstem System reservoirs to record low levels. Water storage in the Mainstem System showed some recovery by the end of 2008; however, storage at the end of 2008 was still appreciably below the total system storage volume and long-term average.

1.2.1 REGULATION OF THE MAINSTEM SYSTEM

The Mainstem System is a hydraulically and electrically integrated system that is regulated to obtain the optimum fulfillment of the multipurpose benefits for which the dams and reservoirs were authorized and constructed. The Congressionally authorized purposes of the Mainstem System, including the Gavins Point Project, are flood control, navigation, hydropower, water supply, water quality, irrigation, recreation, and fish and wildlife (including threatened and endangered species). The Mainstem System is operated under the guidelines described in the Missouri River Mainstem System Master Water Control Manual, (Master Manual) (USACE-RCC, 2004). The Master Manual details regulation for all authorized purposes as well as emergency regulation procedures in accordance with the authorized purposes.

Mainstem System regulation is, in many ways, a repetitive annual cycle that begins in late winter with the onset of snowmelt. The annual melting of mountain and plains snowpacks along with spring and summer rainfall produces the annual runoff into the Mainstem System. In a typical year, mountain snowpack, plains snowpack, and rainfall events, respectively, contribute 50, 25, and 25 percent of the annual runoff to the Mainstem System. After reaching a peak, usually during July, the amount of water stored in the Mainstem System declines until late in the winter when the cycle begins anew. A similar pattern may be found in rates of releases from the Mainstem System, with the higher levels of flow from mid-March to late November, followed by low rates of winter discharge from late November until mid-March, after which the cycle repeats.

To maximize the service to all the authorized purposes, given the physical and authorization limitations of the Mainstem System, the total storage available is divided into four regulation zones that are applied to the individual reservoirs. These four regulation zones are: 1) Exclusive Flood Control Zone, 2) Annual Flood Control and Multiple Use Zone, 3) Carryover Multiple Use Zone, and 4) Permanent Pool Zone.

1.2.1.1 Exclusive Flood Control Zone

Flood control is the only authorized purpose that requires empty space in the reservoirs to achieve the objective. A top zone in each Mainstem System reservoir is reserved for use to meet the flood control requirements. This storage space is used only for detention of extreme or unpredictable flood flows and is evacuated as rapidly as downstream conditions permit, while still serving the overall flood control objective of protecting life and property. The Exclusive Flood Control Zone encompasses 4.7 MAF and represents the upper 6 percent of the total Mainstem System storage volume. This zone, from 73.3 MAF down to 68.7 MAF, is normally empty. The four largest reservoirs, Fort Peck, Garrison, Oahe, and Fort Randall, contain 97 percent of the total storage reserved for the Exclusive Flood Control Zone.

1.2.1.2 Annual Flood Control and Multiple Use Zone

An upper “normal operating zone” is reserved annually for the capture and retention of runoff (normal and flood) and for annual multiple-purpose regulation of this impounded water. The Mainstem System storage capacity in this zone is 11.7 MAF and represents 16 percent of the total system storage volume. This storage zone, which extends from 68.7 MAF down to 57.0 MAF, will normally be evacuated to the base of this zone by March 1 to provide adequate storage capacity for capturing runoff during the next flood season. On an annual basis, water will be impounded in this zone, as required to achieve the Mainstem System flood control purpose, and also be stored in the interest of general water conservation to serve all the other authorized purposes. The evacuation of water from the Annual Flood Control and Multiple Use Zone is scheduled to maximize service to the authorized purposes that depend on water from the system. Scheduling releases from this zone is limited by the flood control objective in that the evacuation must be completed by the beginning of the next flood season. This is normally accomplished as long as the evacuation is possible without contributing to serious downstream flooding. Evacuation is, therefore, accomplished mainly during the summer and fall because Missouri River ice formation and the potential for flooding from higher release rates limit release rates during the December through March period.

1.2.1.3 Carryover Multiple Use Zone

The Carryover Multiple Use Zone is the largest storage zone extending from 57.0 MAF down to 18.0 MAF and represents 53 percent of the total system storage volume. Serving the authorized purposes during an extended drought is an important regulation objective of the Mainstem System. The Carryover Multiple Use Zone provides a storage reserve to support authorized purposes during drought conditions.

Providing this storage is the primary reason the upper three reservoirs of the Mainstem System are so large compared to other Federal water resource projects. The Carryover Multiple Use Zone is often referred to as the "bank account" for water in the Mainstem System because of its role in supporting authorized purposes during critical dry periods when the storage in the Annual Flood Control and Multiple Use Zone is exhausted. Only the reservoirs at Fort Peck, Garrison, Oahe, and Fort Randall have this storage as a designated storage zone. The three larger reservoirs (Fort Peck, Garrison, and Oahe) provide water to the Mainstem System during drought periods to provide for authorized purposes. The storage space assigned to this zone in Fort Randall Reservoir serves a different purpose. It is normally evacuated each year during the fall season to provide recapture space for upstream winter power releases. The recapture results in complete refill of Fort Randall Reservoir during the winter months. During drought periods, the three smaller project (Fort Randall, Big Bend, and Gavins Point) reservoir levels are maintained at the same elevation they would be at if runoff conditions were normal.

1.2.1.4 Permanent Pool Zone

The Permanent Pool Zone is the bottom zone that is intended to be permanently filled with water. The zone provides for future sediment storage capacity and maintenance of minimum pool levels for power heads, irrigation diversions, water supply, recreation, water quality, and fish and wildlife. A drawdown into this zone is generally not scheduled except in unusual conditions. The Mainstem System storage capacity in this storage zone is 18.0 MAF and represents 25 percent of the total storage volume. The Permanent Pool Zone extends from 18.0 MAF down to 0 MAF.

1.2.2 WATER CONTROL PLAN FOR THE MAINSTEM SYSTEM

Variations in runoff into the Mainstem System necessitates varied regulation plans to accommodate the multipurpose regulation objectives. The two primary high-risk flood periods are the plains snowmelt and rainfall period extending from late February through April, and the mountain snowmelt and rainfall period extending from May through July. Also, the winter ice-jam flood period extends from mid-December through February. The highest average power generation period extends from mid-April to mid-October, with high peaking loads during the winter heating season (mid-December to mid-February) and the summer air conditioning season (mid-June to mid-August). The power needs during the winter are supplied primarily with Fort Peck and Garrison Dam releases and the peaking capacity of Oahe and Big Bend Dams. During the spring and summer period, releases are normally geared to navigation and flood control requirements, and primary power loads are supplied using the four lower dams. During the fall when power needs diminish, Fort Randall is normally drawn down to permit generation during the winter period when Oahe and Big Bend peaking-power releases refill the reservoir. The normal 8-month navigation season extends from April 1 through November 30, during which time Mainstem System releases are increased to meet downstream target flows in combination with downstream tributary inflows. Winter releases after the close of the navigation season are much lower and vary, depending on the need to conserve or evacuate storage volumes with downstream ice conditions permitting. Releases and pool fluctuations for fish spawning management generally occur from April 1 through June. Two threatened and endangered bird species, piping plover (*Charadrius melodus*) and least tern (*Sterna antillarum*), nest on "sandbar" areas from early May through mid-August. Other factors may vary widely from year to year, such as the amount of water-in-storage and the magnitude and distribution of inflow received during the coming year. All these factors will affect the timing and magnitude of Mainstem System releases. The gain or loss in the water stored at each reservoir must also be considered in scheduling the amount of water transferred between reservoirs to achieve the desired storage levels and to generate power. These items are continually reviewed as they occur and are appraised with respect to the expected range of regulation.

1.3 GAVINS POINT PROJECT DESCRIPTION

The Gavins Point Project is located on the Nebraska/South Dakota border in northeast Nebraska and southeast South Dakota. Gavins Point Dam is located on the Missouri River at River Mile (RM) 811, 4 miles west of Yankton, South Dakota. The closing of Gavins Point Dam in 1955 resulted in the formation of Gavins Point Reservoir (a.k.a., Lewis and Clark Lake). Table 1-1 provides a summary of selected engineering data for the Gavins Point Project.

1.3.1 GAVINS POINT DAM AND POWERPLANT

Gavins Point Bend Dam is a rolled, earth-filled embankment, with the powerplant at the right abutment (i.e., south end of dam). The spillway is located on the riverward side of the powerplant, separated by an unexcavated portion (Chalk Island). The total embankment length, including the spillway, is 8,700 feet, and the height of the dam is 74 feet above the streambed. No outlet works were constructed at Gavins Point; thus, all releases must be made either through the powerplant or spillway. *(See the front cover of this report for an aerial photo of Gavins Point Dam showing the location of the powerplant and spillway.)*

The Gavins Point powerplant has three units (i.e., turbines) available for power production. Each of the units has a separate intake divided into three water passages by intermediate piers. Trash racks are located at the upstream end of each of the nine water passages, and flow in each of the water passages is controlled by a service gate. The flow of water from the reservoir to the powerplant intake structure is guided by a short, curved approach channel. The approach channel has a bottom elevation of 1155 ft-NGVD29, a bottom width of 240 feet, and 1-on-1 side slopes. Velocity of flow in the approach channel with a plant discharge of 33,000 cfs is approximately 2.0 feet-per-second. About 100 feet upstream from the powerplant intake the bottom of the approach channel slopes downward on a 1 on 4 slope to elevation 1139 to provide sufficient entrance area to the intake. The sides of the approach channel at the intake to the powerplant are closed off by concrete abutment walls. The flow entering the powerplant is confined to rectangular passages formed by the concrete floor, roof, and piers of the intake structure. Water is drawn into the Gavins Point powerplant at the reservoir bottom at an invert elevation of 1139.5 ft-NGVD29; however as noted above, the bottom elevation of the approach channel rises to an elevation of 1155 ft-NGVD29 100 feet upstream of the intake structure. Photo 1-1 provides an upstream view of the powerplant intake to one of the three Gavins Point powerplant units prior to inundation.

Gavins Point Dam is primarily used as a re-regulating dam to level out the release fluctuations from the upper system dams. Due to its smaller size, Lewis and Clark Lake provides very little flood control and is generally maintained in a narrow reservoir elevation range between 1205 and 1207 ft-NGVD29. Due to the limited storage, releases from Gavins Point Dam must be backed up with corresponding release changes out of the upper mainstem projects. Gavins Point is the key location in the initiation of release reductions for downstream flood control.

Table 1-1. Summary of selected engineering data for the Gavins Point Project.

General		
Lake Name	Lewis and Clark Lake	
River Mile (1960 Mileage)	811.1	
Total and Incremental Drainage Area (square miles)[1]	279,480	16,000
Reservoir Length at Top of Carryover Multiple Use Pool (miles)	25	
Shoreline Length at Top of Carryover Multiple Use Pool (miles)	90	
Top Elevation of Carryover Multiple Use Pool (ft-NGVD29)	1208.0	
Year Storage First Available for Regulation of Flows	1955	
Maximum Depth at Dam at “Normal Pool” (feet)	68	
Original “As-Built” Conditions (Year)	(1955)	
Surface Area of Carryover Multiple Use Pool (acres)	31,100	
Capacity of Carryover Multiple Use Pool (acre-feet)	510,000	
Mean Depth at top of Carryover Multiple Use Pool[2] (feet)	16.4	
Most Recent Surveyed Conditions (Year)	(2007)	
Surface Area at top of Carryover Multiple Use Pool (acres)	26,900	
Capacity of Carryover Multiple Use Pool (acre-feet)	393,000	
Mean Depth at top of Multiple Use Pool[2] (feet)	14.6	
Sediment Deposition to Top of Carryover Multiple Use Pool		
Surveyed Sediment Deposition[3] (acre-feet)	117,000	
Years of Sediment Deposition[4] (Survey Year - “As-Built Year”)	52	
Annual Sedimentation Rate[5] (acre-feet/year)	2,250	
Annual Rate of Volume Loss from “As-Built” Condition	0.44%	
Years from “As-Built” to 2010	55	
Estimated Sediment Deposition (acre-feet) through 2010[6]	123,750	
2010 Estimated Capacity of Carryover Multiple Use Pool[7] (acre-feet)	386,250	
Estimated Carryover Multiple Use Pool Capacity Lost through 2010	24.3%	
Operational Details – Historic (1967 through 2010)		
Maximum Recorded Pool Elevation (ft-NGVD29)	1209.1	
Minimum Recorded Pool Elevation (ft-NGVD29)	1199.8	
Average Daily Pool Elevation (ft-NGVD29)	1206.8	
Maximum Recorded Daily Inflow (cfs)	74,000	
Maximum Recorded Daily Outflow (cfs)	70,100	
Average Annual Inflow (ac-ft)	19,674,000	
Average Annual Outflow (ac-ft)	19,631,000	
Operational Details – Current (2010)		
Maximum Recorded Pool Elevation (ft-NGVD29)	1209.7	
Minimum Recorded Pool Elevation (ft-NGVD29)	1206.7	
Maximum Recorded Daily Inflow (cfs)	59,000	
Maximum Recorded Daily Outflow (cfs)	59,500	
Total Inflow (% of Average Annual)	21,862,000	(111%)
Total Outflow (% of Average Annual)	23,921,000	(122%)
Power Tunnel Entrance Invert Elevation	1139.5 ft-NGVD29 (Bottom)	

Note: All elevations given are in the NGVD 29 datum.

(1) Total drainage area is Missouri River headwaters to Gavins Point Dam. Incremental drainage area is from Fort Randall Dam to Gavins Point Dam.

(2) Mean Depth to top of Carryover Multiple Use Pool = Capacity of Carryover Multiple Use Pool (divided by) Surface Area of Carryover Multiple Use Pool.

(3) Surveyed Sediment Deposition is for the capacity (ac-ft) below the top of the Carryover Multipurpose Use Pool = “As-Built” capacity of Carryover Multiple Use Pool (minus) most recent surveyed capacity of Carryover Multiple Use Pool.

(4) Years of Sediment Deposition = year of most recent survey (minus) the “as-built” year.

(5) Annual Sedimentation Rate (ac-ft/yr) = Survey Sediment Deposition / Years of Sediment Deposition.

(6) Estimated Sediment Deposition through 2010 = Annual Sedimentation Rate (times) Years from “As-Built” to 2010.

(7) Current Capacity of Carryover Multiple Use Pool (ac-ft) = “As-Built” Capacity of Carryover Multiple Use Pool (minus) Current Estimated Capacity of Carryover Multiple Use Pool.

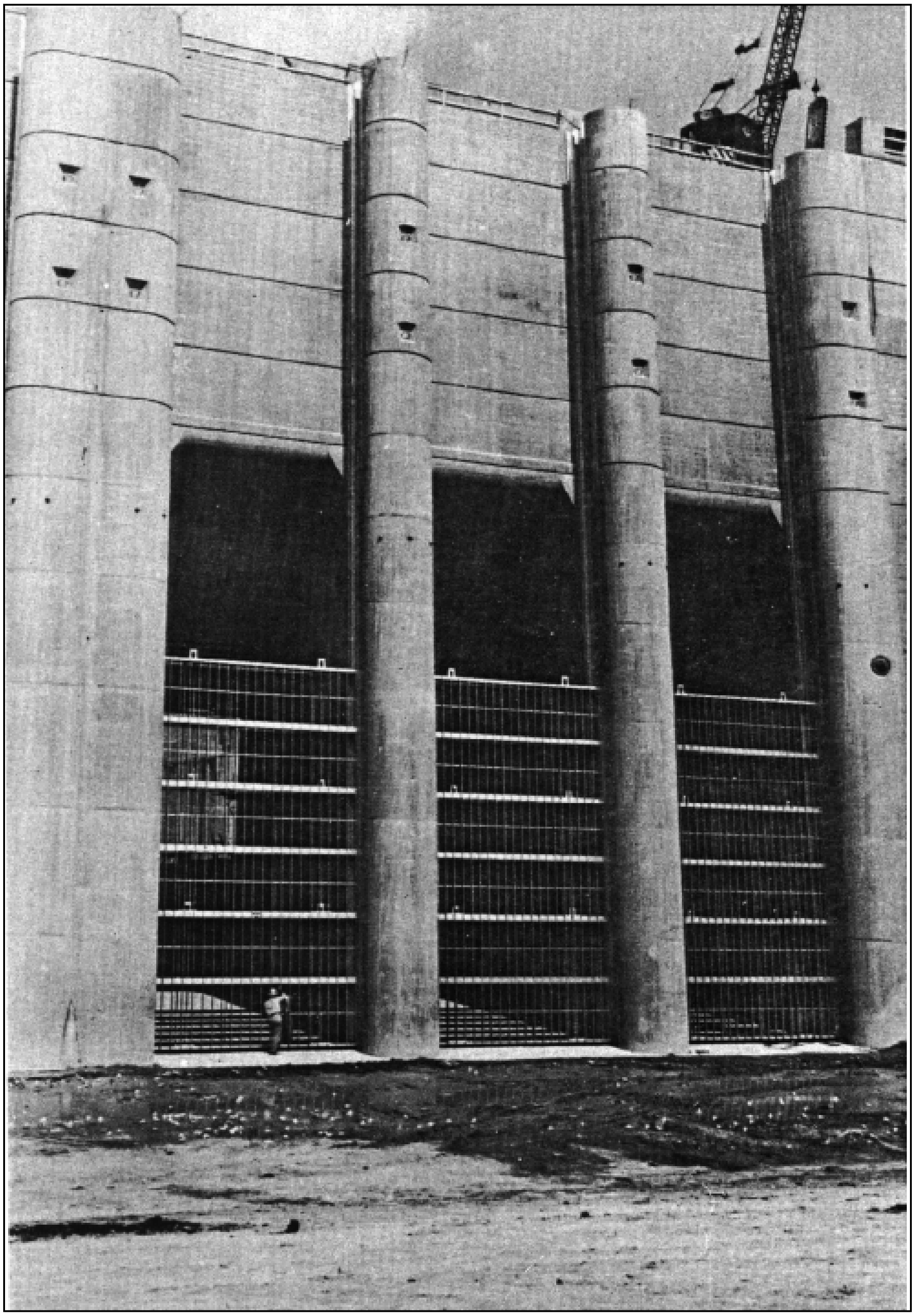

Photo 1-1. Upstream view of the intake to Unit 1 at the Gavins Point powerplant, prior to inundation, with the lower three sections of trash racks in place.

1.3.2 LEWIS AND CLARK LAKE

The closing of Gavins Point Dam in 1955 resulted in the formation of Lewis and Clark Lake. When at an operating pool elevation of 1207.5 ft-NGVD29, the reservoir is currently about 25 miles long, has about 90 miles of shoreline, covers about 27,000 acres, and has a storage volume of about 400,000 acre-ft. Table 1-2 summarizes how the surface area, volume, mean depth, and retention time of Lewis and Clark Lake vary with pool elevations. Major tributaries contributing to Lewis and Clark Lake are the Missouri and Niobrara Rivers. Habitat for two endangered species, pallid sturgeon and interior least tern, and one threatened species, piping plover, occur within the project area. Lewis and Clark Lake is a source water supply (drinking water) for Springfield, SD (RM832) , Cedar Knox Rural Water District (RM823 – Crofton, Fordice, St. Helena, and Obert, NE), and Bon Homme-Yankton Rural Water District (RM818 – 15 communities). Gavins Point is an important recreational resource and a major visitor destination in South Dakota and Nebraska.

Table 1-2. Surface area, volume, mean depth, and retention time of Lewis and Clark Lake at different pool elevations based on 2007 survey.

Elevation (Feet-msl)	Surface Area (Acres)	Volume (Acre-Feet)	Mean Depth (Feet)*	Retention Time (Years)**
1210	29,956	450,070	15.0	0.02293
1205	23,029	318,732	13.8	0.01624
1200	18,819	215,126	11.4	0.01096
1195	14,278	132,308	9.3	0.00674
1190	9,921	71,711	7.2	0.00365
1185	5,202	35,027	6.7	0.00178
1180	3,393	14,543	4.3	0.00074
1175	1,067	3,855	3.6	0.00020
1170	371	728	2.0	0.00004

Average Annual Inflow (1967 through 2010) = 19.67 Million Acre-Feet.
Average Annual Outflow: (1967 through 2010) = 19.63 Million Acre-Feet.
* Mean Depth = Volume ÷ Surface Area.
** Retention Time = Volume ÷ Average Annual Outflow.
Note: Exclusive Flood Control Zone (elev. 1210-1208 ft-NGVD29), Annual Flood Control and Multiple Use Zone (elev. 1208-1204.5 ft-NGVD29), Carryover Multiple Use Zone (none), and Permanent Pool Zone (elev. 1204.5-1160 ft-NGVD29). All elevations are in the NGVD 29 datum.

1.3.3 GAVINS POINT DAM TAILWATERS

The 59-mile reach of the Missouri River downstream of Gavins Point Dam starting at RM 811 down to Ponca, NE (RM 752) has been designated a National Recreational River under the Federal Wild and Scenic Rivers Act. This reach of the river has not been channelized by construction of dikes and revetments, and has a meandering channel with many chutes, backwater marshes, sandbars, islands, and variable current velocities. Snags and deep pools are also common. Although this portion of the river includes some bank stabilization structures, the river remains fairly wide. Bank erosion rates since the closure of Gavins Point Dam in 1956 have averaged 132 acres per year between Gavins Point Dam and Ponca, Nebraska (RM753) compared to a pre-dam rate of 202 acres per year. The rate of erosion had been declining since 1975 and then dramatically increased during the high flow years of 1995 through 1997. Major tributaries to this reach of the Missouri River are the James and Vermillion Rivers which flow into the Missouri River, respectively, at RM800 and RM772.

1.4 WATER QUALITY MANAGEMENT CONCERNS AT THE GAVINS POINT PROJECT

1.4.1 APPLICABLE WATER QUALITY STANDARDS

1.4.1.1 Lewis and Clark Lake

Pursuant to the Federal Clean Water Act, the State of South Dakota has designated the following water quality-dependent beneficial uses for Lewis and Clark Lake: recreation (i.e., immersion and limited-contact), warmwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e., irrigation and stock watering), commerce and industrial waters, and fish and wildlife propagation. The State of Nebraska has designated the following beneficial uses to Lewis and Clark Lake: primary contact recreation, Class I warmwater aquatic life, drinking water supply, agricultural water supply, industrial water supply, and aesthetics. The uses designated by the States of South Dakota and Nebraska to Lewis and Clark Lake are consistent with each other.

1.4.1.2 Gavins Point Dam Tailwaters (Missouri River)

The States of Nebraska and South Dakota have designated water quality-dependent beneficial uses, in their State water quality standards, for the Missouri River downstream of Gavins Point Dam. Nebraska has designated the following uses to the Missouri River immediately downstream of Gavins Point Dam: primary contact recreation, warmwater aquatic life, drinking water supply, agricultural water supply, and aesthetics. Nebraska has also designated the reach between Gavins Point Dam and Ponca State Park as Outstanding State Resource Waters for "Tier 3" protection under the State's water quality standard's antidegradation policy. South Dakota has designated the following uses for all of the Missouri River within the state downstream of Gavins Point Dam: primary contact recreation, warmwater fishery, drinking water supply, and industrial water supply.

1.4.2 FEDERAL CLEAN WATER ACT SECTION 303(D) IMPAIRED WATERBODY LISTINGS AND FISH CONSUMPTION ADVISORIES

1.4.2.1 Lewis and Clark Lake

Nebraska has placed Lewis and Clark Lake on the State's 2010 Section 303(d) list of impaired waters for impairment to the Aquatic Life use due to nutrients (total phosphorus and chlorophyll *a*). South Dakota has not listed Lewis and Clark Lake on their 303(d) list. Neither of the two States has issued fish consumption advisories for the reservoir.

1.4.2.2 Gavins Point Dam Tailwaters (Missouri River)

The States of Nebraska and South Dakota have not listed the Gavins Point Dam tailwaters area of the Missouri River as impaired under the Federal Clean Water Act's Section 303(d) provisions. Neither State has issued a fish consumption advisory for the tailwaters area.

2 WATER QUALITY MONITORING CONSIDERATIONS

2.1 WATER QUALITY MONITORING OBJECTIVES

2.1.1 GENERAL MONITORING OBJECTIVES

The Omaha District has identified purposes and general monitoring objectives for surface water quality monitoring to facilitate implementation of the District's Water Quality Management Program (USACE, 2011). The water quality monitoring conducted at the Gavins Point Project over the 3-year period, 2008 through 2010, was implemented to address the following general monitoring objectives:

- Characterize the spatial and temporal distribution of surface water quality conditions at District Projects.
- Identify pollutants and their sources that are affecting surface water quality and the aquatic environment at District Projects.
- Determine if surface water quality conditions at District Projects or attributable to District operations or reservoir regulation (i.e., downstream conditions resulting from reservoir discharges) meet applicable Federal, Tribal, and State water quality standards.
- Determine if surface water quality conditions at District Projects or attributable to District operations or reservoir regulation are improving, degrading, or staying the same over time.
- Apply water quality models to assess surface water quality conditions at District Projects.
- Collect the information needed to design, engineer, and implement measures or modifications at District Projects to enhance surface water quality and the aquatic environment.

2.1.2 SPECIFIC MONITORING OBJECTIVES

2.1.2.1 Intensive Water Quality Survey

In addition to the general water quality monitoring objectives, one specific monitoring objective was identified for the intensive water quality survey of the Gavins Point Project:

1) Collect the information needed to allow application and "full calibration" of the current version of the CE-QUAL-W2 hydrodynamic and water quality model to Lewis and Clark Lake.

2.1.2.2 Water Quality Impacts of Constructing Emergent Sandbar Habitat (ESH) in the Headwaters of Lewis and Clark Lake

An investigative study to evaluate the water quality impacts of constructing Emergent Sandbar Habitat (ESH) in the headwaters of Lewis and Clark Lake was conducted in 2008 and the findings of that study are available in the separate report, "Creation of Emergent Sandbar Habitat (ESH) in the Headwaters of Lewis and Clark Lake and the Impacts on Water Quality" (USACE, 2009).

2.2 LIMNOLOGICAL CONSIDERATIONS

2.2.1 VERTICAL AND LONGITUDINAL WATER QUALITY GRADIENTS

The annual temperature distribution represents one of the most important limnological processes occurring within a reservoir. Thermal variation in a reservoir results in temperature-induced density stratification, and an understanding of the thermal regime is essential to water quality assessment. Deep, temperate-zone lakes typically completely mix from the surface to the bottom twice a year (i.e., dimictic). Temperate-zone dimictic lakes exhibit thermally-induced density stratification in the summer and winter

months that is separated by periods of "turnover" in the spring and fall. This stratification typically occurs through the interaction of wind and solar insolation at the lake surface and creates density gradients that can influence lake water quality. During the summer, solar insolation has its highest intensity and the reservoir becomes stratified into three zones: 1) epilimnion, 2) metalimnion, and 3) hypolimnion.

> <u>Epilimnion</u>: The epilimnion is the upper zone that consists of the less dense, warmer water in the reservoir. It is fairly turbulent since its thickness is determined by the turbulent kinetic energy inputs (e.g., wind, convection, etc.), and a relatively uniform temperature distribution throughout this zone is maintained.
>
> <u>Metalimnion</u>: The metalimnion is the middle zone that represents the transition from warm surface water to colder bottom water. There is a distinct temperature gradient through the metalimnion. The metalimnion contains the thermocline that is the plane or surface of maximum temperature rate change.
>
> <u>Hypolimnion</u>: The hypolimnion is the bottom zone of more dense, colder water that is relatively quiescent. Bottom withdrawal or fluctuating water levels in reservoirs, however, may significantly increase hypolimnetic mixing.

Long, dendritic reservoirs with tributary inflows located a considerable distance from the outflow and unidirectional flow from headwater to dam develop gradients in space and time (USACE, 1987). Although these gradients are continuous from headwater to dam, three characteristic zones result: a riverine zone, a zone of transition, and a lacustrine zone (USACE, 1987).

> <u>Riverine Zone:</u> The riverine zone is relatively narrow and well mixed, and there is a significant decrease in water current velocities. Advective forces are still sufficient to transport significant quantities of suspended particles, such as silts, clays, and organic particulate. Light penetration in this zone is minimal and may be the limiting factor that controls primary productivity in the water column. The decomposition of tributary organic loadings often creates a significant oxygen demand, but an aerobic environment is maintained because the riverine zone is generally shallow and well mixed. Longitudinal dispersion may be an important process in this zone.
>
> <u>Zone of Transition:</u> Significant sedimentation occurs through the transition zone, with a subsequent increase in light penetration. Light penetration may increase gradually or abruptly, depending on the flow regime. At some point within the mixed layer of the zone of transition, a compensation point between the production and decomposition of organic matter should be reached. Beyond this point, production of organic matter within the reservoir mixed layer should begin to dominate.
>
> <u>Lacustrine Zone:</u> The lacustrine zone is characteristic of a lake system. Sedimentation of inorganic particulate is low. Light penetration is sufficient to promote primary production, with nutrient levels the limiting factor and production of organic matter exceeds decomposition within the mixed layer. Entrainment of metalimnetic and hypolimnetic water, particulate, and nutrients may occur through internal waves or wind mixing during the passage of large weather fronts. Hypolimnetic mixing may be more extensive in reservoirs than "natural" lakes because of bottom withdrawal. In addition, an intake structure may simultaneously remove water from the hypolimnion and metalimnion.

When tributary inflow enters a reservoir, it displaces the reservoir water. If there is no density difference between the inflow and reservoir waters, the inflow will mix with the reservoir water as the inflow water moves toward the dam. However, if there are density differences between the inflow and reservoir waters, the inflow moves as a density current in the form of overflows, interflows, or underflows. Internal mixing is the term used to describe mixing within a reservoir from such factors as wind, Langmuir circulation, convection, Kelvin-Helmholtz instabilities, and outflow (USACE, 1987).

2.2.2 CHEMICAL CHARACTERISTICS OF RESERVOIR PROCESSES

2.2.2.1 Constituents

Some of the most important chemical constituents in reservoir waters that affect water quality are needed by aquatic organisms for survival. These include oxygen, carbon, nitrogen, and phosphorus. Other important constituents are silica, manganese, iron, and sulfur.

Dissolved oxygen: Oxygen is a fundamental chemical constituent of waterbodies that is essential to the survival of aquatic organisms and is one of the most important indicators of reservoir water quality conditions. The distribution of dissolved oxygen (DO) in reservoirs is a result of dynamic transfer processes from the atmospheric and photosynthetic sources to consumptive uses by the aquatic biota. The resulting distribution of DO in the reservoir water strongly affects the solubility of many inorganic chemical constituents. Often, water quality control or management approaches are formulated to maintain an aerobic, or oxic (i.e., oxygen-containing), environment. Oxygen is produced by aquatic plants (phytoplankton and macrophytes) and is consumed by aquatic plants, other biological organisms, and chemical oxidations. In reservoirs, the DO demand may be divided into two separate but highly interactive fractions: sediment oxygen demand (SOD) and water column oxygen demand.

> *Sediment oxygen demand*: The SOD is typically highest in the upstream area of the reservoir just below the headwaters. This is an area of transition from riverine to lake characteristics. It is relatively shallow but stratifies. The loading and sedimentation of organic matter is high in this transition area and, during stratification, the hypolimnetic DO to satisfy this demand can be depleted. If anoxic conditions develop, they generally do so in this area of the reservoir and progressively move toward the dam during the stratification period. The SOD is relatively independent of DO when DO concentrations in the water column are greater than 3 to 4 mg/l but becomes limited by the rate of oxygen supply to the sediments.

> *Water column oxygen demand*: A characteristic of many reservoirs is a metalimnetic minimum in DO concentrations, or negative heterograde oxygen curve (Figure 2-1). Density interflows not only transport oxygen-demanding material into the metalimnion but can also entrain reduced chemicals from the upstream anoxic area and create additional oxygen demand. Organic matter and organisms from the mixed layer settle at slower rates in the metalimnion because of increased viscosity due to lower temperatures. Since this labile organic matter remains in the metalimnion for a longer time period, decomposition occurs over a longer time, exerting a higher oxygen demand. Metalimnetic oxygen depletion is an important process in deep reservoirs. A hypolimnetic oxygen demand generally starts at the sediment/water interface unless underflows contribute organic matter that exerts a significant oxygen demand. In addition to metalimnetic DO depletion, hypolimnetic DO depletion also is important in shallow, stratified reservoirs since there is a smaller hypolimnetic volume of oxygen to satisfy oxygen demands than in deeper reservoirs.

> *Dissolved oxygen distribution*: Two basic types of vertical DO distribution may occur in the water column: an orthograde and clinograde DO distribution (Figure 2-1). In the orthograde distribution, DO concentration is a function primarily of temperature since DO consumption is limited. The clinograde DO profile is representative of more productive, nutrient-rich reservoirs where the hypolimnetic DO concentration progressively decreases during stratification and can occur during both summer and winter stratification periods.

Inorganic carbon: Inorganic carbon represents the basic building block for the production of organic matter by plants. Inorganic carbon can also regulate the pH and buffering capacity or alkalinity of aquatic systems. Inorganic carbon exists in a dynamic equilibrium in three major forms: carbon dioxide (CO_2), bicarbonate ions (HCO_3), and carbonate ions (CO_3). Carbon dioxide is readily soluble in water and some

CO_2 remains in a gaseous form, but the majority of the CO_2 forms carbonic acid that dissociates rapidly into HCO_3 and CO_3 ions. This dissociation results in a weakly alkaline system (i.e., pH ≈ 7.1 or 7.2). There is an inverse relationship between pH and CO_2. The pH increases when aquatic plants (phytoplankton or macrophytes) remove CO_2 from the water to form organic matter through photosynthesis during the day. During the night when aquatic plants respire and release CO_2, the pH decreases. The extent of this pH change provides an indication of the buffering capacity of the system. Weakly buffered systems with low alkalinities (i.e., <500 microequivalents per liter) experience larger shifts in pH than well-buffered systems (i.e., >1,000 microequivalents per liter).

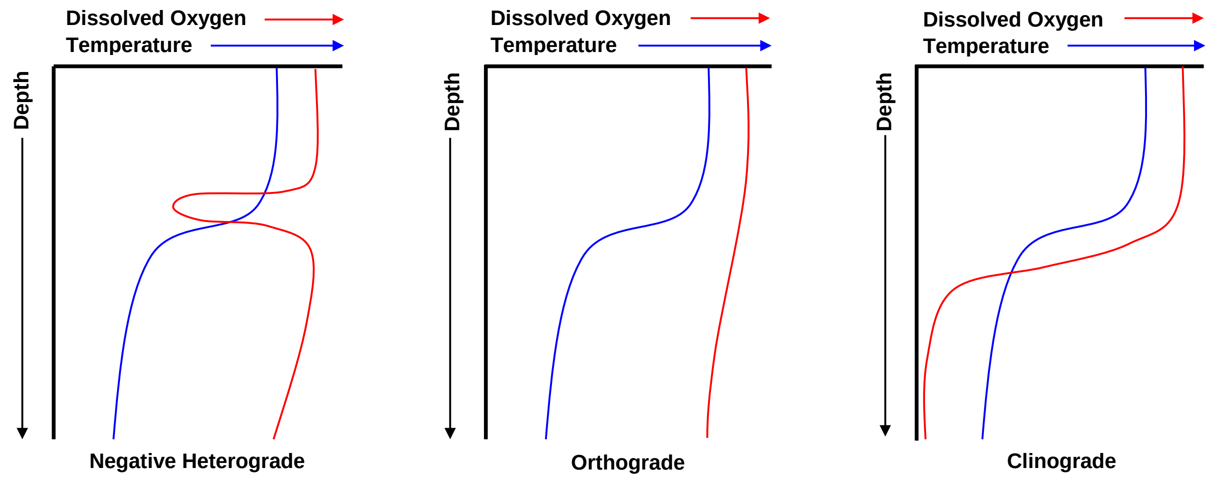

Figure 2-1. Vertical oxygen concentrations possible in thermally stratified lakes.

Nitrogen: Nitrogen is important in the formulation of plant and animal protein. Nitrogen, similar to carbon, also has a gaseous form. Many species of cyanobacteria can use or fix elemental or gaseous N_2 as a nitrogen source. The most common forms of nitrogen in aquatic systems are ammonia (NH_3-N), nitrite (NO_2-N), and nitrate (NO_3-N). All three forms are transported in water in a dissolved phase. Ammonia results primarily from the decomposition of organic matter. Nitrite is primarily an intermediate compound in the oxidation or nitrification of ammonia to nitrate, while nitrate is the stable oxidation state of nitrogen and represents the other primary inorganic nitrogen form, besides NH_3, used by aquatic plants.

Phosphorus: Phosphorus is used by both plants and animals to form enzymes and vitamins and to store energy in organic matter. Phosphorus has received considerable attention as the nutrient controlling algal production and densities and associated water quality problems. The reasons for this emphasis are: phosphorus tends to limit plant growth more than the other major nutrients; phosphorus does not have a gaseous phase and ultimately originates from the weathering of rocks; removal of phosphorus from point sources can reduce the growth of aquatic plants; and the technology for removing phosphorus is more advanced and less expensive than nitrogen removal. Phosphorus is generally expressed in terms of the chemical procedures used for measurement: total phosphorus, particulate phosphorus, dissolved or filterable phosphorus, and soluble reactive phosphorus. Phosphorus is a very reactive element; it reacts with many cations such as iron and calcium and is readily sorbed on particulate matter such as clays, carbonates, and inorganic colloids. Since phosphorus exists in a particulate phase, sedimentation represents a continuous loss from the water column to the sediment. Sediment phosphorus, then, may exhibit longitudinal gradients in reservoirs similar to sediment silt/clay gradients. Phosphorus contributions from sediment under anoxic conditions and macrophyte decomposition are considered internal phosphorus sources or loads, and are in a chemical form readily available for plankton uptake and use. Internal phosphorus loading can represent a major portion of the total phosphorus budget.

Silica: Silica is an essential component of diatom algal frustules or cell walls. Silica uptake by diatoms can markedly reduce silica concentrations in the epilimnion and initiate a seasonal succession of diatom species. When silica concentrations decrease below 0.5 mg/l, diatoms generally are no longer competitive with other phytoplankton species.

Other nutrients: Iron, manganese, and sulfur concentrations generally are adequate to satisfy plant nutrient requirements. Oxidized iron (III) and manganese (IV) are quite insoluble in water and occur in low concentrations under aerobic conditions. Under aerobic conditions, sulfur usually is present as sulfate.

2.2.2.2 Anaerobic (Anoxic) Conditions

When dissolved oxygen concentrations are reduced to approximately 2 to 3 mg/l, the oxygen regime is considered hypoxic. Anoxic conditions occur when there is a complete lack of oxygen. When hypoxic conditions occur in the hypolimnion, the oxygen regime at the sediment/water interface is generally considered anoxic, and anaerobic processes begin to occur in the sediment interstitial water. Nitrate reduction to ammonium and/or N_2O or N_2 (denitrification) is considered to be the first phase of the anaerobic process and places the system in a slightly reduced electrochemical state. Ammonium-nitrogen begins to accumulate in the hypolimnetic water. The presence of nitrate prevents the production of additional reduced forms such as manganese (II), iron (II), or sulfide species. Denitrification probably serves as the main mechanism for removing nitrate from the hypolimnion. Following the reduction or denitrification of nitrate, manganese species are reduced from insoluble forms (i.e., Mn (IV)) to soluble manganous forms (i.e., Mn (II)), which diffuse into the overlying water column. Nitrate reduction is an important step in anaerobic processes since the presence of nitrate in the water column will inhibit manganese reduction. As the electrochemical potential of the system becomes further reduced, iron is reduced from the insoluble ferric (III) form to the soluble ferrous (II) form and begins to diffuse into the overlying water column. Phosphorus, in many instances, is also transported in a complexed form with insoluble ferric (III) species; therefore, the reduction and solubilization of iron also result in the release and solubilization of phosphorus into the water column. The sediments may serve as a major phosphorus source during anoxic periods and a phosphorus sink during aerobic periods. During this period of anaerobiosis, microorganisms also are decomposing organic matter into lower molecular weight acids and alcohols such as acetic, fulvic, humic, and citric acids and methanol. These compounds may also serve as trihalomethane precursors (low-molecular weight organic compounds in water; i.e., methane, formate acetate), which, when subject to chlorination during water treatment, form trihalomethanes, or THMs (carcinogens). As the system becomes further reduced, sulfate is reduced to sulfide, which begins to appear in the water column. Sulfide will readily combine with soluble reduced iron (II), however, to form insoluble ferrous sulfide, which precipitates out of solution. If the sulfate is reduced to sulfide and the electrochemical potential is strongly reducing, methane formation from the reduced organic acids and alcohols may occur. Consequently, water samples from anoxic depths will exhibit these chemical characteristics.

Anaerobic processes are generally initiated in the upstream portion of the hypolimnion where organic loading from the inflow is relatively high and the volume of the hypolimnion is minimal, so oxygen depletion occurs rapidly. Anaerobic conditions are generally initiated at the sediment/water interface and gradually diffuse into the overlying water column and downstream toward the dam. Anoxic conditions may also develop in a deep pocket near the dam due to decomposition of autochthonous organic matter settling to the bottom. This anoxic pocket, in addition to expanding vertically into the water column, may also move upstream and eventually meet the anoxic zone moving downstream.

Anoxic conditions are generally associated with the hypolimnion, but anoxic conditions may occur in the metalimnion. The metalimnion may become anoxic due to microbial respiration and

decomposition of plankton settling into the metalimnion, microbial metabolism of organic matter entering as an interflow, or entrainment of anoxic hypolimnetic water from the upper portion of the reservoir.

2.2.3 BIOLOGICAL CHARACTERISTICS AND PROCESSES

2.2.3.1 Microbiological

The microorganisms associated with reservoirs may be categorized as pathogenic or nonpathogenic. Pathogenic microorganisms are of a concern from a human health standpoint and may limit recreational and other uses of reservoirs. Nonpathogenic microorganisms are important in that they often serve as decomposers of organic matter and are a major source of carbon and energy for a reservoir. Microorganisms generally inhabit all zones of the reservoir as well as all layers. Seasonally high concentrations of bacteria will occur during the warmer months, but they can be diluted by high discharges. Anaerobic conditions enhance growth of certain bacteria while aeration facilitates the use of bacterial food sources. Microorganisms, bacteria in particular, are responsible for mobilization of contaminants from sediments.

2.2.3.2 Photosynthesis

Oxygen is a by-product of aquatic plant photosynthesis, which represents a major source of oxygen for reservoirs during the growing season. Oxygen solubility is less during the period of higher water temperatures, and diffusion may also be less if wind speeds are lower during the summer than the spring or fall. Biological activity and oxygen demand typically are high during thermal stratification, so photosynthesis may represent a major source of oxygen during this period. Oxygen supersaturation in the euphotic zone can occur during periods of high photosynthesis.

2.2.3.3 Plankton

Phytoplankton influence dissolved oxygen and suspended solids concentrations, transparency, taste and odor, aesthetics, and other factors that affect reservoir uses and water quality objectives. Phytoplankton are a primary source of organic matter production and form the base of the autochthonous food web in many reservoirs since fluctuating water levels may limit macrophyte and periphyton production. Phytoplankton can be generally grouped as diatoms, green algae, cyanobacteria, or cryptomonad algae. Chlorophyll *a* represents a common variable used to estimate phytoplankton biomass.

Seasonal succession of phytoplankton species is a natural occurrence in reservoirs. The spring assemblage is usually dominated by diatoms and cryptomonads. Silica depletion in the photic zone and increased settling as viscosity decreases because of increased temperatures usually result in green algae succeeding the diatoms. Decreases in nitrogen or a decreased competitive advantage for carbon at higher pH may result in cyanobacteria succeeding the green algae during summer and fall. Diatoms generally return in the fall, but cyanobacteria, greens, or diatoms may cause algae blooms following fall turnover when hypolimnetic nutrients are mixed throughout the water column. The general pattern of seasonal succession of phytoplankton is fairly constant from year to year. However, hydrologic variability, such as increased mixing and delay in the onset of stratification during cool, wet spring periods, can maintain diatoms longer in the spring and shift or modify the successional pattern of algae in reservoirs.

Phytoplankton grazers can reduce the abundance of algae and alter their successional patterns. Some phytoplankton species are consumed and assimilated more readily and are preferentially selected by consumers. Single-celled diatom and green algae species are readily consumed by zooplankton, while filamentous cyanobacteria are avoided by zooplankters. Altering the fish population can result in a change in the zooplankton population that can affect the phytoplankton population.

2.2.3.4 <u>Organic Carbon and Detritus</u>

Total organic carbon (TOC) is composed of dissolved organic carbon (DOC) and particulate organic carbon (POC). Detritus represents that portion of the POC that is nonliving. Nearly all the TOC of natural waters consists of DOC and detritus, or dead POC. The processes of decomposition and consumption of TOC are important in reservoirs and can have a significant effect on water quality.

DOC and POC are decomposed by microbial organisms. This decomposition exerts an oxygen demand that can remove dissolved oxygen from the water column. During stratification, the metalimnion and hypolimnion become relatively isolated from sources of dissolved oxygen, and depletion can occur through organic decomposition. There are two major sources of this organic matter: allochthonous (i.e., produced outside the reservoir) and autochthonous (i.e., produced within the reservoir). Allochthonous organic carbon in small streams may be relatively refractory since it consists of decaying terrestrial vegetation that has washed or fallen into the stream. Larger rivers, however, may contribute substantial quantities of riverine algae or periphyton that decompose rapidly and can exert a significant oxygen demand. Autochthonous sources include dead plankton settling from the mixed layers and macrophyte fragments and periphyton transported from the littoral zone. These sources are also rapidly decomposed.

POC and DOC absorbed onto sediment particles may serve as a major food source for aquatic organisms. The majority of the phytoplankton production enters the detritus food web with a minority being grazed by primary consumers (USACE, 1987). While autochthonous production is important in reservoirs, typically as much as three times the autochthonous production may be contributed by allochthonous material (USACE, 1987).

2.2.4 BOTTOM WITHDRAWAL RESERVOIRS

Bottom withdrawal structures are located near the deepest part of a reservoir. Bottom withdrawal removes hypolimnetic water and nutrients and may promote movement of interflows or underflow into the hypolimnion. They release cold water from the deep portion of the reservoir; however, this water may be hypoxic or anoxic during periods of stratification. Bottom outlets can cause density interflows or underflows (e.g., flow laden with sediment or dissolved solids) through the reservoir and generally provide little or no direct control over release water quality.

As previously discussed, the intake structure at Gavins Point Dam withdraws water from the bottom of Lewis and Clark Lake. The powerplant intake structure has separate intakes, divided into three water passages by intermediate piers, for each of the three units (Photo 1-1). The flow of water from the reservoir to the powerplant intake structure is guided by a short, curved approach channel. The approach channel has a bottom elevation of 1155 ft-NGVD29. About 100 feet upstream of the powerplant intake, the bottom of the approach channel slopes downward on a 1 on 4 slope to elevation 1139 ft-NGVD29 at the intake. Because of the available fetch and shallower maximum depth (approximately 68 feet) near the dam, Lewis and Clark Lake is seemingly polymixic and a hypolimnion with degraded dissolved oxygen conditions forms intermittently.

2.3 APPLICATION OF THE CE-QUAL-W2 WATER QUALITY MODEL TO THE MISSOURI RIVER MAINSTEM SYSTEM PROJECTS

Water quality data must be applied to understand and manage water resources effectively. Application of appropriate mathematical models promotes efficient and effective use of data. Models are powerful tools for guiding project operations, refining water quality sampling programs, planning project modifications, evaluating management scenarios, improving project benefits, and illuminating new or

understanding complex phenomena. CE-QUAL-W2 is a "state-of-the-art" water quality model that can greatly facilitate addressing reservoir water quality management issues.

CE-QUAL-W2 is a water quality and hydrodynamic model in two dimensions (longitudinal and vertical) for rivers, estuaries, lakes, reservoirs, and river basin systems. CE-QUAL-W2 models basic physical, chemical, and biological processes such as temperature, nutrient, algae, dissolved oxygen, organic matter, and sediment relationships. Version 1.0 of the model was developed by the Corps' Water Quality Modeling Group at the Waterways Experiment Station in the late 1980's. The current model release is Version 3.6 and is supported by the Corps' Engineer Research and Development Center (ERDC) and Portland State University.

2.3.1 PAST APPLICATION OF THE CE-QUAL-W2 MODEL

Version 2.0 of the CE-QUAL-W2 model was applied to four of the upper Mainstem System Projects in the early 1990's (i.e., Fort Peck, Garrison, Oahe, and Fort Randall). The application of the model was part of the supporting technical documentation of the Environmental Impact Statement (EIS) that was prepared for the Missouri River Master Water Control Manual Review and Update Study. The results of the model application were included as an Appendix to the Review and Update Study – "Volume 7B: Environmental Studies, Reservoir Fisheries, Appendix C – Coldwater Habitat Model, Temperature and Dissolved Oxygen Simulations for the Upper Missouri River Reservoirs" (Cole et. al., 1994). The report (Cole et. al, 1994) provided results of applying the model to the four reservoirs regarding the effects of operational changes on reservoir coldwater fish habitat. This early application of the model represents the best results that could be obtained based on the model version and water quality data available at that time, and it provided predictive capability for coldwater fish habitat regarding two system operational variables of concern – end-of-month stages and monthly average releases.

Although application of the CE-QUAL-W2 (Version 2.0) model met its intended purpose at the time, a lack of available water data placed limitations on its full utilization. These limitations were discussed in the Master Water Control Review and Update Study report (Cole et. al, 1994). The following excerpts are taken from that report:

> *"Typically, dissolved oxygen (DO) is modeled along with a full suite of water quality variables including algal/nutrient interactions. Lack of available algal/nutrient data necessitated a different approach. DO was assumed to be a function of sediment and water column oxygen demands which were adjusted during calibration to reproduce the average DO depletion during summer stratification. The drawback to this approach is that operational changes which might affect algal/nutrient interactions cannot be predicted. Results from this study show only how physical factors relating to changes in reservoir stage and discharge affect DO."*
>
> *"As a result, model predictions during scenario runs represent only how physical factors affect DO and do not include the effects of reservoir operations on algal/nutrient dynamics and their effects on DO. To include algal/nutrient effects would require at least one year's worth of detailed algal/nutrient data for each reservoir that were not and could not be made available during the time frame of this study."*
>
> *"Steps should be taken to obtain a suitable database that can be used to calibrate the entire suite of water quality algorithms in the model. It is almost a certainty that water quality issues will remain important in the future."*

The current version of the CE-QUAL-W2 model has incorporated numerous enhancements over the Version 2.0 model that was applied to the four Mainstem System Projects in the early 1990's. These

enhancements, among other things, include improvements to the numerical solution scheme, water quality algorithms, two-dimensional modeling of the water basin, code efficiencies, and user-model interface. Communication with the author of the past application of the Version 2.0 model to the Mainstem System Projects and current model support personnel indicated that the Omaha District should pursue implementing the current version of the model (personal communication, Thomas M. Cole, USACE/ERDC).

2.3.2 Future Application of the CE-QUAL-W2 Model

As part of its Water Quality Management Program, the Omaha District initiated the application of the CE-QUAL-W2 (Version 3.2) model to the Mainstem System Projects. The District is approaching the model application as an ongoing, iterative process. Data will be collected, and the model will be run and continuously calibrated as new information is gathered. The goal is to have a fully functioning model in place for all the Mainstem System Projects that meets the uncertainty requirements of decision-makers.

The current plan for applying the model to a single project will encompass a 5-year period. During years 1 through 3 an intensive water quality survey will be conducted to collect the water quality data needed to fully apply the model. The water quality data will be compiled and a Special Water Quality Report assessing the water quality data will be compiled in year 4 (this report). Application and calibration of the model will be initiated in year 5. Once the model has been applied and calibrated, a Water Quality Modeling report will be prepared documenting the application of the model to the specific reservoir. The calibrated model will then be used to facilitate the development of a Project-Specific Water Quality Report and water quality management objectives for the specific reservoir. The current plan is to stagger the application of the model by annually beginning the application process at a different Mainstem System project. The current order for applying the model to the Projects is: 1) Garrison Project, 2) Fort Peck Project, 3) Oahe Project, 4) Fort Randall Project, 5) Big Bend Project, and 6) Gavins Point Project. Eventually it is hoped that the CE-QUAL-W2 models developed for each of the Projects can be linked and used to make integrated water quality management decisions throughout the Mainstem System.

2.3.3 Current Application of the CE-QUAL-W2 Model to Lake Sharpe

The 3-year intensive water quality survey was conducted at the Gavins Point Project during 2008 through 2010, and the application and calibration of the model to Lewis and Clark Lake is planned for 2013. The Gavins Point Project will be the sixth Mainstem System Project on which the updated CE-QUAL-W2 model is applied. A Water Quality Modeling Report will be prepared at a future date describing the application and calibration of the CE-QUAL-W2 model to Lewis and Clark Lake.

3 DATA COLLECTION METHODS

3.1 DATA COLLECTION DESIGN

3.1.1 MONITORING LOCATIONS

The Omaha District collected ambient water quality data at 14 locations at the Gavins Point Project during the 3-year period 2008 through 2010. Of the 14ambient locations, 10 were located on Lewis and Clark Lake, 2 were located on the major inflows to the reservoir (i.e., Missouri River and Niobrara River), 1 was located at the Gavins Point Dam powerplant, and 1 was located on the Gavins Point Dam tailwaters. An additional 20 sites were monitored in 2008 as part of a Special Study to evaluate potential water quality impacts from constructing ESH in the upper reaches of Lewis and Clark Lake. Table 3-1 describes the monitoring locations and Figure 3-1 shows their locations.

Table 3-1. Location and description of monitoring sites that were sampled by the Omaha District for water quality at the Gavins Point Project during the 3-year period 2008 through 2010.

Station Number	Name	Location	Site Type	Latitude	Longitude
GTPNFMORR1	Missouri River near Running Water, SD	At SD Hwy 37bridge crossing	Inflow	-----	-----
GTPNFNIOR1	Niobrara River near Niobrara, NE	At NE Hwy 12 bridge crossing	Inflow	-----	-----
GPTLK0811A	Lewis & Clark Lake – Near Dam	Reservoir (RM0811), Deepwater	Lake	42° 51’ 49.1”	97° 30’ 21.2”
GPTLK0815DW	Lewis and Clark Lake – Weigand Area	Reservoir (RM1815), Deepwater	Lake	42° 50’ 36.8”	97° 34’ 37.1”
GPTLK0819DW	Lewis and Clark Lake – Bloomfield Area	Reservoir (RM1819), Deepwater	Lake	42° 51’ 00.6”	97° 38’ 34.2”
GPTLK0822DW	Lewis and Clark Lake – Devils Nest Area	Reservoir (RM1822), Deepwater	Lake	42° 50’ 36.2”	97° 41’ 43.5”
GPTLK0825DW	Lewis and Clark Lake – Charley Creek Area	Reservoir (RM1825), Deepwater	Lake	42° 50’ 26.8”	97° 45’ 19.6”
GPTLKBACT1	Lewis and Clark Lake – Bacteria 1	Marina Sailing Beach	Beach/Bacteria	42° 52’ 16.0”	97° 29’ 46.4”
GPTLKBACT2	Lewis and Clark Lake – Bacteria 2	Midway Beach East Beach	Beach/Bacteria	42° 51’ 42.9”	97° 31’ 27.7”
GPTLKBACT3	Lewis and Clark Lake – Bacteria 3	Midway Beach West Beach	Beach/Bacteria	42° 51’ 39.2”	97° 31’ 48.5”
GPTLKBACT4	Lewis and Clark Lake – Bacteria 4	Gavins Point Beach	Beach/Bacteria	42° 51’ 29.2”	97° 32’ 52.2”
GPTLKBACT5	Lewis and Clark Lake – Bacteria 5	Weigand Beach	Beach/Bacteria	42° 50’ 15.7”	97° 34’ 54.2”
GTPPP1	Gavins Point Dam Powerplant	“Raw Water” Supply Line	Outflow	-----	-----
GPTRRTW1	Gavins Point Dam Tailwaters	Missouri River RM810 – 1-mile downstream of Gavins Point Dam	Outflow	42° 51’00.4”	97° 27’ 49.9”
ESH Sites	Lewis and Clark Lake – ESH Sites	Point locations upstream of ESH construction site	Special Study	2 Sites	2 Sites
ESH Transects	Lewis and Clark Lake – ESH Transects	Transects downstream of ESH construction site	Special Study	20 Sites	20 Sites

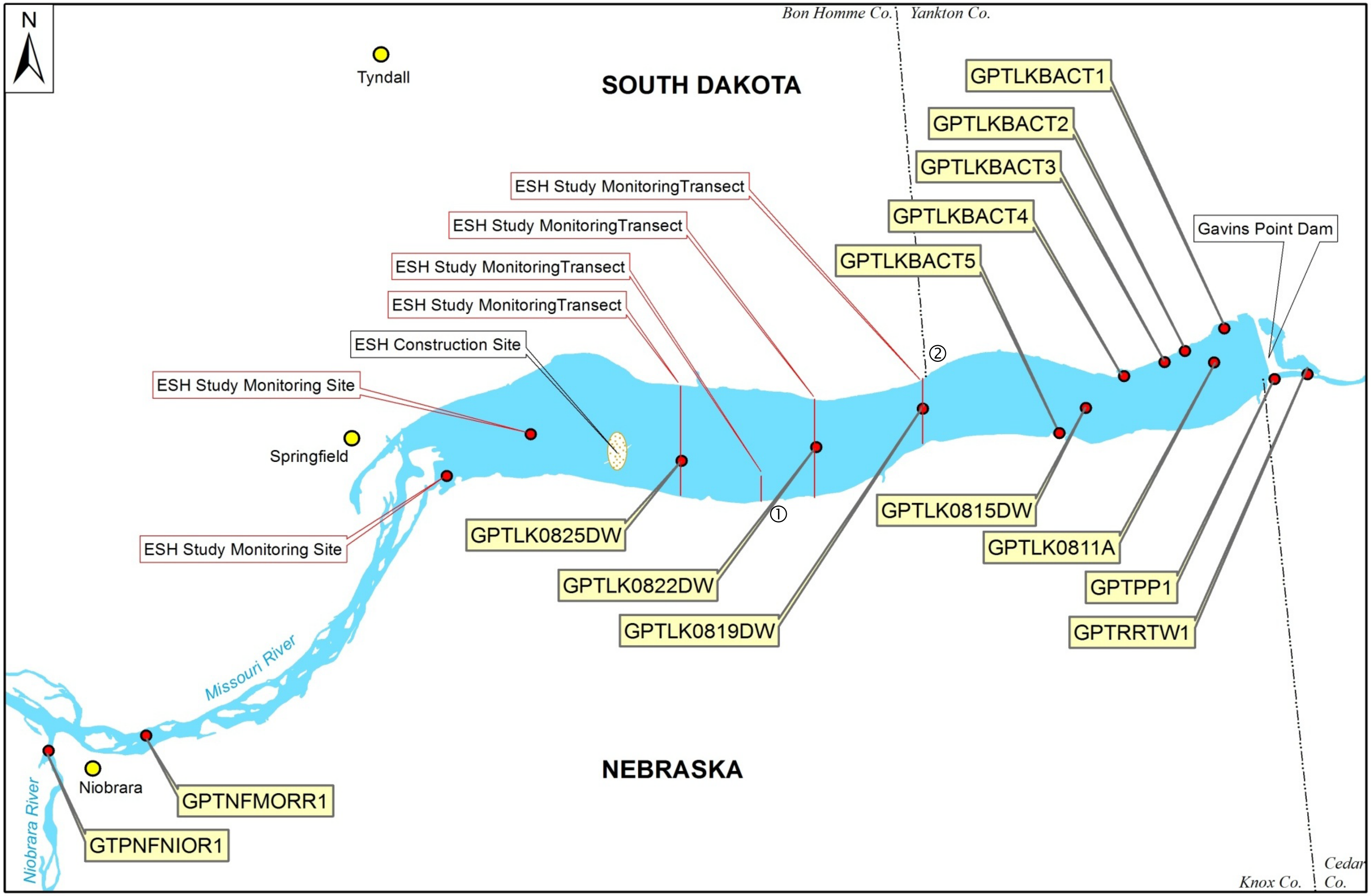

Figure 3-1. Location of sites where water quality monitoring was conducted by the District at the Gavins Point Project during the 3-year period 2008 through 2010.
[① = Location of Cedar Knox Rural Water District intake. ② = Location of Bon Homme-Yankton Rural Water District intake.]

The ambient monitoring sites were categorized into four types: 1) lake, 2) beach/bacteria, 3) inflow, and 4) outflow (Table 3-1). The lake sites were meant to represent "deepwater" pelagic conditions and were established at the deepest part of the reservoir in the area being monitored. The five reservoir monitoring sites (i.e., GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW) were approximately equally spaced along the submerged old Missouri River channel from near the dam (RM811) to RM825 – a total distance of approximately 14 miles. The two inflow stations (i.e., GPTNFMORR1 and GPTNFNIOR1) were located on the Missouri River at RM840 and on the Niobrara River approximately 2 miles upstream from its confluence with the Missouri River. Outflow site GTPPP1 was located in the Gavins Point Dam powerplant, and monitored water quality conditions from the "raw water" supply line in the powerplant that was indicative of the Gavins Point Dam discharge. Outflow site GPTRRTW1 was located on the Gavins Point Dam tailwaters at RM810, approximately 1 mile downstream from the dam. The ambient lake sites are believed to be associated with the following reservoir zones: Lacustrine Zone (GPTLK0811A, GPTLK0815DW, and GPTPP1), Zone of Transition (GPTLK0819DW and GPTLK0822DW), and Riverine Zone (GPTLK0825DW).

A description of the ESH monitoring sites are given in the document, "Water Quality Office Report: Creation of Emergent Sandbar Habitat (ESH) in the headwaters of Lewis and Clark Lake and the Impacts on Water Quality" (USACE, 2009).

3.1.2 MEASUREMENTS, SAMPLE TYPES, AND COLLECTION FREQUENCY

3.1.2.1 <u>Ambient Reservoir Monitoring Stations</u>

Monitoring at the reservoir monitoring sites consisted of field measurements and collection of depth-discrete "grab" samples for laboratory analysis. Field measurements consisted of depth-profiles for selected parameters and a surface Secchi depth measurement. Two depth-discrete grab samples, near-surface (i.e., ½ the measured Secchi depth) and near-bottom (i.e., within 1 meter of the reservoir bottom), were collected. Measurements and samples were collected monthly during the period April/May/June through September.

3.1.2.2 <u>Reservoir Beach Monitoring</u>

Monitoring at the five beach sites on Lewis and Clark Lake was conducted under a monitoring project that included bacteria monitoring at District Projects in Nebraska with designated swimming beaches.

3.1.2.3 <u>Inflow Monitoring Stations</u>

Monitoring at the Missouri and Niobrara River inflow sites consisted of field measurements and collection of grab samples. A near-surface grab sample was collected from near the bank in an area of faster current. Depth-profile measurements and depth-discrete (i.e., near-surface and near-bottom) samples were collected at the Missouri River inflow site during 2010. Monitoring at these sites occurred monthly during the period April through September.

3.1.2.4 <u>Outflow Monitoring Stations</u>

Monitoring at the Gavins Point powerplant was conducted under a monitoring project that included monitoring at all six of the Missouri River mainstem powerplants. Monitoring consisted of year-round hourly data-logging of water temperature, dissolved oxygen, and conductivity; monthly collection of grab samples for laboratory analyses. Measurements and samples were collected from a "flow-chamber" drawing water from the "raw-water" supply line in the powerplant. At the Gavins Point

Project, the raw water supply elevation is at 1176.7 feet-msl, 37 feet above the reservoir bottom. The water passes through the intake structure, enters a 14-inch raw water header pipe and travels 50 feet. The water then enters a 1-inch PVC pipe and travels an additional 70 feet to the water quality monitoring location.

Monitoring at the Gavins Point tailwaters was conducted under a monitoring project that included monitoring at nine sites along the Missouri River from the Fort Randall Dam tailwaters to Rulo, Nebraska. Monitoring consisted of collecting monthly, year-round field measurements and water quality samples for laboratory analyses. During 2008 and 2009 water quality measurements and samples were collected from a near-bank location. During May through October 2010, depth-profile measurements and depth-discrete (i.e., near-surface, middle, and near-bottom) samples were collected from the river thalweg.

3.1.2.5 <u>ESH Special Study</u>

A description of the measurements, sample types, and collection frequency of the ESH Special Study monitoring is given in the document, "Water Quality Office Report: Creation of Emergent Sandbar Habitat (ESH) in the headwaters of Lewis and Clark Lake and the Impacts on Water Quality" (USACE, 2009).

3.1.3 PARAMETERS MEASURED AND ANALYZED

3.1.3.1 <u>Water Quality Parameters</u>

The water quality parameters that were measured and analyzed at the various monitoring sites, outside of the ESH Special Study, are given in Table 3-2. Water quality parameters measured and analyzed as part of the ESH Special Study are given in the document, "Water Quality Office Report: Creation of Emergent Sandbar Habitat (ESH) in the headwaters of Lewis and Clark Lake and the Impacts on Water Quality" (USACE, 2009).

3.1.3.2 <u>Explanatory Variables</u>

Explanatory variables that were quantified included inflow discharge, outflow discharge, and reservoir pool elevation. Inflow discharge at station GTPNFMORR1 was taken as the recorded discharge at Fort Randall Dam plus the recorded flow on the lower reaches of the Niobrara River near Verdel, Nebraska (USGS gage 06465500). Inflow discharge at station GPTNFNIOR1 was determined from the USGS gage (06465500) on the Niobrara River near Verdel. Outflow discharge from Gavins Point Dam and the pool elevation of Lewis and Clark Lake were obtained from Gavins Point Project records.

3.2 WATER QUALITY MEASUREMENT AND SAMPLING METHODS

3.2.1 FIELD MEASUREMENTS

Depth-profile and surface measurements for water temperature, dissolved oxygen (mg/l and % saturation), pH, conductivity, Oxidation-Reduction Potential (ORP), turbidity, and chlorophyll *a* were taken using a "HydroLab". Profile measurements were taken at 1-meter intervals. The HydroLab was operated as specified in the USACE – Water Quality Unit's Standard Operating Procedures (SOPs) Number WQ-21201, "Using a HydroLab DS5 to Directly Measure Water Quality" (USACE, 2010). Secchi transparency was measured in accordance with the USACE – Water Quality Unit's SOP Number WQ-21202, "Determining Secchi Depth" (USACE, 2004b).

Table 3-2. Water quality parameters measured and analyzed at the identified monitoring sites.

Parameter	Monitoring Site Number				
	GPTLK0811A GPTLK0819DW GPTLK0825DW	**GPTLK0815DW GPTLK0822DW**	**GPTPP1**	**GPTNFNIOR1 GPTNFMORR1 GPTRRTW1**	**GPTLKBACT1 GPTLKBACT2 GPTLKBACT3 GPTLKBACT4 GPTLKBACT5**
Alkalinity	✓		✓	✓	
Carbon, Total Organic	✓		✓	✓	
Carbonaceous BOD				GPTRRTW1	
Chemical Oxygen Demand, Total	✓		✓	✓	
Chlorophyll *a*	✓			GPTRRTW1	
Color, True	✓		✓	✓	
Dissolved Solids, Total	✓		✓	✓	
Microcystins	✓		✓		GPTLKBACT5
Nitrogen, Total Ammonia	✓		✓	✓	
Nitrogen, Total Kjeldahl	✓		✓	✓	
Nitrogen, Nitrate-Nitrite	✓		✓	✓	
Phosphorus, Dissolved	✓		✓	✓	
Phosphorus, Orthophosphate	✓		✓	✓	
Phosphorus, Total	✓		✓	✓	
Plankton – Zooplankton Taxa. Id. and Biovolume	✓				
Plankton – Phytoplankton Taxa. Id. and Biovolume	✓			GPTRRTW1	
Silica, Dissolved and Total	✓			✓	
Sulfate, Dissolved	✓		✓	✓	
Suspended Sediment, Total				GPTNFMORR1 GPTRRTW1	
Suspended Solids, Total	✓		✓	✓	
Metal Scan, Total and Dissolved			✓	✓	
Pesticide Scan, Total			✓	✓	
Pesticides, Immunoassay (Acetochlor, Atrazine, Metolachlor)				GPTRRTW1	
E. coli Bacteria					✓
Fecal Coliform Bacteria					✓
Secchi Depth/Transparency	✓	✓		GPTRRTW1	
Field Measurements (HydroLab)*	Depth Profile	Depth Profile	Grab Sample	Grab Sample Depth Profile	
Continuous Monitoring**			✓		

* Water temperature, dissolved oxygen, pH, conductivity, ORP, turbidity, chlorophyll *a*.
** Water temperature, dissolved oxygen, and conductivity.

3.3 ANALYTICAL METHODS

Laboratory analyses of all collected water quality samples were done by the District's contract laboratory, Midwest Laboratories, Inc. in Omaha, Nebraska. The analytical methods, detection limits, and reporting limits for the analysis of the collected water quality samples are given in Table 3-3. Plankton analyses were done by a laboratory (i.e., BSA Environmental Services, Inc., Beachwood, Ohio) under contract to Midwest Laboratories.

Table 3-3. Methods, detection limits, and reporting limits for laboratory analyses.

Analyte	Method	Detection Limit	Reporting Limit
Alkalinity, Total	SM2320B	4 mg/l	10 mg/l
Carbon, Total Organic(TOC)	SM5310B	0.2 mg/l	1 mg/l
Carbonaceous Biochemical Oxygen Demand	SM5210.B	1 mg/l	5 mg/l
Chlorophyll *a*	SM - 10200H2	1 ug/l	3 ug/l
Color, True	ASTMD1252	2 SU	5 SU
Dissolved Solids, Total	SM2540C	4 mg/l	10 mg/l
Microcystins (Immunoassay)	Rapid Assay	0.2 ug/l	1 ug/l
Nitrogen, Total Ammonia as N	EPA - 350.1	0.02 mg/l	0.1 mg/l
Nitrogen, Total Kjeldahl as N	EPA - 351.3	0.2 mg/l	0.5 mg/l
Nitrogen, Nitrate/Nitrite as N	EPA - 353.2	0.02 mg/l	0.1 mg/l
Phosphorus, Dissolved	SM4500PF	0.02 mg/l	0.05 mg/l
Phosphorus, Orthophosphate	EPA - 365.4	0.02 mg/l	0.05 mg/l
Phosphorus, Total as P	SM4500PF	0.02 mg/l	0.05 mg/l
Silica, Total and Dissolved	EPA - 200.7	0.5 mg/l	1 mg/l
Sulfate, Dissolved	EPA - 300.0	1 mg/l	5 mg/l
Suspended Sediment, Total	SM2540D	4 mg/l	10 mg/l
Suspended Solids, Total	SM2540D	4 mg/l	10 mg/l
Metals Scan, Dissolved and Total:			
Antimony	EPA - 200.8	0.5 ug/l	2 ug/l
Arsenic, Silver	EPA - 200.7	1 ug/l	3 ug/l
Beryllium	EPA - 200.7	2 ug/l	5 ug/l
Cadmium	EPA - 200.8	0.2 ug/l	1 ug/l
Calcium, Chromium, Magnesium, Nickel, Zinc	EPA - 200.7	10 ug/l	30 ug/l
Copper, Manganese	EPA - 200.7	2 ug/l	10 ug/l
Iron	EPA - 200.7	40 ug/l	120 ug/l
Lead, Thallium	EPA - 200.8	0.5 ug/l	2 ug/l
Mercury	EPA - 7470	0.4 ug/l	1.2 ug/l
Selenium	EPA – 200.8	1 ug/l	3 ug/l
Pesticide Scan*:	EPA - 507	~0.05 ug/l	~0.1 ug/l
Pesticides Immunoassay (Acetochlor, Atrazine, Metolachlor)	Immunoassay	0.05 ug/l	0.1 ug/l
E. coli Bacteria	SM9223B	1 cfu/100ml	1 cfu/100ml
Fecal Coliform Bacteria	SM9222D	1 cfu/100ml	1 cfu/100ml

* Pesticide scan included: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, cycloate, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, isopropalin, metolachlor, metribuzin, molinate, oxiadiazon, oxyfluorfen, pebulate, pendimethalin, phorate, profluralin, prometon, propachlor, propazine, simazine, terbufos, triallate, trifluralin, and vernolate.

4 DATA ASSESSMENT METHODS

4.1 GENERAL WATER QUALITY CONDITIONS

Statistical analyses were performed on the water quality monitoring data collected at reservoir, inflow, and outflow sites during the 3-year period 2008 through 2010. Descriptive statistics (i.e., mean, median, minimum, maximum) were calculated to describe central tendencies and the range of observations. Where appropriate, monitoring results were compared to defined water quality standards criteria for the States of Nebraska and South Dakota.

Spatial variation of selected water quality parameters in Lewis and Clark Lake were evaluated. Longitudinal contour plots were constructed for water temperature, dissolved oxygen, and turbidity to display likely conditions in Lewis and Clark Lake from its upper reaches to Gavins Point Dam. The longitudinal contour plots were constructed using the "Hydrologic Information Plotting Program" included in the "Data Management and Analysis System for Lakes, Estuaries, and Rivers" (DASLER-X) software developed by HydroGeoLogic, Inc. (Hydrogeologic Inc., 2008). Secchi depth measurements collected along Lewis and Clark Lake were evaluated and are displayed using a box plot. The variation of selected parameters with depth was evaluated at site GPTLK0811A by comparing near-surface and near-bottom conditions. Near-surface conditions were represented by samples collected at ½ the metered Secchi depth, and near-bottom conditions were represented by samples collected within 1-meter of the reservoir bottom. Water quality conditions represented by paired near-surface and near-bottom samples are graphically displayed by box plots. A paired two-tailed t-test was used to determine if the paired near-surface and near-bottom samples were significantly different ($\alpha = 0.05$).

4.2 TROPHIC STATUS

A Trophic State Index (TSI) was calculated, as described by Carlson (1977). TSI values were determined from Secchi depth transparency, total phosphorus, and chlorophyll *a* measurements. Values for these three parameters were converted to an index number ranging from 0 to 100 according to the following equations:

$$\text{TSI(Secchi Depth)} = \text{TSI(SD)} = 10[6 - (\ln SD/\ln 2)]$$
$$\text{TSI(Chlorophyll } a) = \text{TSI(Chl)} = 10[6 - ((2.04\text{-}0.68 \ln Chl)/\ln 2)]$$
$$\text{TSI(Total Phosphorus)} = \text{TSI(TP)} = 10[6 - (\ln (48/TP)/\ln 2)]$$

Accurate TSI values from total phosphorus depend on the assumptions that phosphorus is the major limiting factor for algal growth and that the concentrations of all forms of phosphorus present are a function of algal biomass. Accurate TSI values from Secchi depth transparency depend on the assumption that water clarity is primarily limited by phytoplankton biomass. Carlson indicates that the chlorophyll TSI value may be a better indicator of a lake's trophic conditions during mid-summer when algal productivity is at its maximum, while the total phosphorus TSI value may be a better indicator in the spring and fall when algal biomass is below its potential maximum. Calculation of TSI values from data collected from a lake's epilimnion during summer stratification provide the best agreement between all of the index parameters and facilitate comparisons between lakes. A TSI average value, calculated as the average of the three individually determined TSI values, is used by the District as an overall indicator of a reservoir's trophic state. The District uses the criteria defined in Table 4-1 for determining lake trophic status from TSI values.

Table 4-1. Lake trophic status based on calculated TSI values.

TSI	Trophic Condition
0-35	Oligotrophic
36-50	Mesotrophic
51-55	Moderately Eutrophic
56-65	Eutrophic
66-100	Hypereutrophic

Existing trophic conditions were assessed for Lewis and Clark Lake based on the monitoring conducted during the 3-year period 2008 through 2010. The data evaluated consisted of Secchi depth measurements and total phosphorus and chlorophyll *a* analytical results obtained at the reservoir sites GPTLK0811A, GPTLK0819DW, and GPTLK0825DW. TSI values were calculated and compared to the above criteria.

4.3 PLANKTON COMMUNITY

4.3.1 PHYTOPLANKTON

Assessment of the phytoplankton community was based on grab samples that were analyzed by a contract laboratory. Laboratory analyses consisted of identification of phytoplankton taxa to the lowest practical level and quantification of taxa biovolume. These results were used to determine the relative abundance of phytoplankton taxa at the division level based on the measured biovolumes.

4.3.2 ZOOPLANKTON

Assessment of the zooplankton community was based on vertical tow samples (i.e., near-bottom to surface) that were collected in May, July, and September of 2010. Zooplankton samples were analyzed by a contract laboratory, and consisted of identification of zooplankton taxa to the lowest practical level and quantification of taxa biomass. These results were used to determine the relative abundance of zooplankton taxa at the division level based on the measured biomass.

4.4 IMPAIRMENT OF DESIGNATED WATER QUALITY-DEPENDENT BENEFICIAL USES

Water quality-dependent beneficial uses are designated to waterbodies at the Gavins Point Project by the States of Nebraska and South Dakota in their water quality standards, and criteria are defined to protect these uses (see Section 1.4.1). Water quality data collected at the Gavins Point Project during the 3-year period 2008 through 2010 were assessed to determine if monitored water quality conditions indicate impairment of the designated beneficial uses. Impairment of beneficial uses was assessed using the methodologies defined by the Nebraska Department of Environmental Quality and the South Dakota Department of Environment and Natural Resources to prepare the States' latest Integrated Report for Surface Water Quality Assessment (NDEQ, 2010 and SDDENR, 2010).

4.4.1 NEBRASKA IMPAIRMENT ASSESSMENT CRITERIA

4.4.1.1.1 Assessment of Physicochemical Data

Nebraska water quality standards define acute and chronic numeric criteria for the protection of aquatic life and maximum criteria for the protection of public drinking and agricultural water supplies. Nebraska deems a designated use to be impaired if measured water quality conditions indicate that numeric criteria are exceeded more than 10 percent of the time over an assessed 5-year period (NDEQ,

2009). To address the uncertainty associated with water quality data, the application of the 10 percent exceedance criterion is based on the number of measurements for the appropriate water quality criteria. Table 4-2 gives the Nebraska assessment measures regarding sample size and the number of exceedances that indicate an impaired use (i.e., 10% exceedance) at a 90% confidence level (i.e., α= 0.10). Consistent with U.S. Environmental Protection Agency (EPA) guidance, the assess of toxic ("priority") pollutants will consider a waterbody impaired for aquatic life if an acute criteria for a toxic pollutant is exceeded more than once every 3 years on average.

Table 4-2. State of Nebraska Assessment Measures for Sample Size and Number of Exceedances Required to Determine an Impaired Use (i.e., 10% Exceedance).

Sample Size (n)	Number of Observations Exceeding a Criterion Required to Define an Impaired Use	Sample Size (n)	Number of Observations Exceeding a Criterion Required to Define an Impaired Use
<12	3	56 - 63	10
12 – 18	4	64 - 71	11
19 - 25	5	72 - 79	12
26 - 32	6	80 - 88	13
33 - 40	7	89 - 96	14
41 - 47	8	97 - 100	15
48 - 55	9	>100	Not Defined

4.4.1.1.2 Assessment of Fecal Coliform and *E. coli* Bacteria Data

Table 4-3 summarizes the Nebraska measures for the assessment of the Primary Contact Recreation Beneficial Use using fecal coliform and *E. coli* bacteria data.

Table 4-3. State of Nebraska measures for the assessment of the Primary Contact Recreation Beneficial Use using fecal coliform and *E. coli* bacteria data.

Parameter	Water Quality Criteria (Geometric Mean)	Supported	Impaired
Fecal Coliform	≤ 200cfu/100ml	Season geometric mean ≤ 200cfu/100ml	Season geometric mean > 200cfu/100ml
E. coli	≤ 126cfu/100ml	Season geometric mean ≤ 126cfu/100ml	Season geometric mean > 126cfu/100ml

4.4.1.1.3 Assessment of Cyanobacteria Toxins

Table 4-4 summarizes the Nebraska measures for the assessment of the Primary Contact Recreation Beneficial Use using cyanobacteria toxins data.

Table 4-4. State of Nebraska measures for the assessment of the Primary Contact Recreation Beneficial Use using cyanobacteria toxins data.

Supported	Impaired
≤ 10% of samples exceed 20 ug/l	> 10% of samples exceed 20 ug/l

4.4.1.1.4 Assessment of Reservoir Sedimentation

It is the State of Nebraska's position that excess sediment delivered to a lake can cause several problems including "objectionable colors, turbidity, and deposits." Deposition of sediment can displace or eliminate fish spawning and rearing and other aquatic habitats. Also, the recreation area of a lake can be reduced or rendered undesirable. Nebraska uses two measurements to assess lake sedimentation regarding the use of aesthetics: impoundment volume loss and sedimentation rate. Both the lake volume loss and sedimentation rate are based on the "as-built" conditions of the lake. Table 4-5 summarizes the Nebraska criteria for the assessment of lakes regarding sedimentation.

Table 4-5. State of Nebraska measures for the assessment of lake sedimentation data.

Minimum Assessment Period	Supported	Impaired
≥5 Years	Volume loss < 25%, and Annual sedimentation rate ≤0.75%	Volume loss ≥ 25%, and Annual sedimentation rate >0.75%

4.4.1.1.5 Assessment of Reservoir Nutrient Data

A meeting between EPA and NDEQ was held on August 25, 2009 to establish mutually agreeable nutrient and chlorophyll targets for Beneficial Use Support assessments to be reported in the 2010 Integrated Report. Resulting from this meeting were total phosphorus, total nitrogen, and chlorophyll targets for two regions of the state for the protection of aquatic life. The criteria that apply all the Corps reservoirs in the Omaha District are chlorophyll *a* 10 ug/l, total nitrogen 1 mg/l, and total phosphorus 50 ug/l. The data requirements for assessing nutrient data include:

- The established targets will apply to lake growing season conditions which is defined as being from May 1 through September 30 and data outside this date range will not be used in Beneficial Use Support assessments.
- Data must represent epilimnetic conditions in the lake or reservoir.
- While there are no spatial requirements for the data, the data must be representative of lake or reservoir conditions.
- An adequate dataset will contain 10 samples collected over two growing seasons, preferably five samples from each year.
- All valid data must have met NDEQ Quality Assurance/Quality Control requirements.

Total phosphorus, total nitrogen, and chlorophyll targets will be evaluated independently by comparing them to growing season mean concentrations. If growing season mean concentrations exceed any of the three targets, an impaired status to the Aquatic Life Use will be noted and the cause of this impairment will be listed as "nutrients". While the criteria described above will be used for Section 303(d) nutrient listings in the 2010 Integrated Report, future listings and de-listings of lakes and reservoirs for nutrients will be based on methodologies, targets and/or water quality standards that are applicable to that assessment cycle.

4.4.2 SOUTH DAKOTA IMPAIRMENT ASSESSMENT CRITERIA

The State of South Dakota requires that beneficial use support determinations be based on sufficient and credible data. Data must meet QA/QC requirements that assure data are representative. The decision criteria regarding data age, sample size, and exceedances that the State of South Dakota uses to determine beneficial use support are given in Table 4-6, Table 4-7, and Table 4-8.

Table 4-6. Data age requirements specified by South Dakota to consider data representative of actual conditions.

Description	Criteria Used
CONVENTIONAL PARAMETRS (e.g., dissolved oxygen, total suspended solids, pH, temperature, fecal coliform bacteria, etc.) TOXIC PARAMETERS (e.g., metals, ammonia, etc.)	• STREAMS: Data must be less than 5 years old. • LAKES: Data must be less than 10 years old. Unless there is justification that data is (or is not) representative of current conditions.

Table 4-7. Sample size requirements specified by South Dakota to consider data representative of actual conditions.

Description	Criteria Used
CONVENTIONAL PARAMETERS (e.g., DO, TSS, pH, temperature, fecal coliform bacteria, etc.)	• STREAMS: At least 20 samples for any one parameter are usually required at any site. The sample threshold is reduced to 10 samples if 3 or more samples exceed daily maximum water quality standards. • LAKES: At least two independent years of sample data and at least two sampling events per year.
TOXIC PARAMETERS (e.g., metals, ammonia, etc.)	• STREAMS: At least one water quality sampling event. • LAKES: At least one fish flesh sampling event. More than one exceedance of toxic criteria within the past 3 years.

Table 4-8. Decision criteria for beneficial use support determination identified by South Dakota.

Description	Criteria
CONVENTIONAL PARAMETERS (e.g., DO, TSS, pH, temperature, fecal coliform bacteria, etc.) Required percentage of samples exceeding water quality standards to consider segment water quality-limited.	STREAMS: >10% (or 3 or more exceedances between 10 and 19 samples) for daily maximum criteria. >10% (2 or more exceedances between 2 and 19 samples) for 30-day average criteria. LAKES: >10% exceedances when 20 or more samples are available. If <20 samples available, 3 exceedances are considered impaired. If one surface exceedance was observed for water temperature, DO, or pH; lake profile data is used to make use support determination. Lakes are considered fully supporting the aquatic life beneficial use if profile data indicate a region within the water column where temperature, pH, and dissolved oxygen meet numeric water quality standards criteria. If a region does not exist, the lake is listed for the parameter in exceedance.
TOXIC PARAMETERS (e.g., metals, ammonia, etc.) Required percentage of samples exceeding water quality standards to consider segment water quality-limited.	STREAMS: More than one exceedance of toxic criteria within the past 3 years for both the acute and chronic standard. LAKES: If flesh samples are above the Federal Drug Administration's recommended action levels (such as 1 part per million for mercury).

4.5 TIME-SERIES PLOTS OF FLOW, WATER TEMPERATURE, AND DISSOLVED OXYGEN OF WATER DISCHARGED THROUGH GAVINS POINT DAM

Time series plots were prepared for conditions measured at the Gavins Point Dam powerplant during the 2008 through 2010 period. Discharge was plotted with hourly temperature and dissolved oxygen measurements. Plots were for measurements taken on water drawn from the “raw water” supply line within the powerplant (site GTPPP1).

5 LEWIS AND CLARK LAKE WATER QUALITY CONDITIONS

5.1 EXISTING WATER QUALITY CONDITIONS – 2008 THROUGH 2010

5.1.1 STATISTICAL SUMMARY AND WATER QUALITY STANDARDS ATTAINMENT

Table 5-1, Table 5-2, Table 5-3, Table 5-4, and Table 5-5 summarize the water quality conditions that were monitored at the five ambient monitoring sites on Lewis and Clark Lake during the 3-year period of 2008 through 2010. A review of these results indicated possible water quality concerns regarding total phosphorus and chlorophyll *a*. The Nebraska "nutrient criteria" for total phosphorus and chlorophyll *a* applicable to Lewis and Clark Lake were regularly exceeded throughout the reservoir.

5.1.2 WATER TEMPERATURE

5.1.2.1 Annual Temperature Regime

The water temperature regime of Lewis and Clark Lake can be described by an annual cycle consisting of eight thermal periods: 1) winter ice cover, 2) spring turnover, 3) spring isothermal conditions, 4) late-spring/early-summer warming, 5) mid-summer maximum thermal warming, 6) late-summer/early-fall cooling, 7) fall turnover, and 8) fall isothermal conditions leading to winter ice cover. During the winter ice-cover period, Lewis and Clark Lake can exhibit an inverse thermal gradient as warmer, more dense water (i.e., 4°C) settles to the bottom. Thermal stratification of Lewis and Clark Lake is influenced by the reservoir's depth and the management of its outflows for hydropower production, least turn and plover habitat, and navigation support. Compared to the four larger Missouri River mainstem reservoirs, Lewis and Clark Lake is relatively shallow with a maximum depth of 68 feet near the dam. The shallower depth, given the available fetch, allows Lewis and Clark Lake to periodically mix to the bottom during the summer thermal stratification period. The periodic mixing of Lewis and Clark Lake results in the reservoir being polymixic with irregular periods of the thermal stratification.

Table 5-1. Summary of monthly (May through September) water quality conditions monitored in Lewis and Clark Lake near Gavins Point Dam (Site GPTLK0811A) during the 3-year period 2008 through 2010.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	15	1206.5	1206.4	1205.4	1207.5	-----	-----	-----
Water Temperature (°C)	0.1	177	20.6	21.3	9.3	26.5	27(1,2,6), 29(1,2,6)	0	0%
Dissolved Oxygen (mg/l)	0.1	177	8.8	8.9	1.7	15.1	5(1,7)	9	5%
Dissolved Oxygen (% Sat.)	0.1	177	101.4	103.4	19.6	165.4	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	159	9.1	9.0	4.5	15.1	5(1,7)	2	1%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	18	6.2	7.1	1.7	10.7	5(1,7)	7[F]	39%[F]
Specific Conductance (umhos/cm)	1	176	712	709	663	778	2,000(4)	0	0%
pH (S.U.)	0.1	177	8.4	8.5	7.8	9.0	6.5(1,3,7), 9.0(1,3,6), 9.5(5,6)	0	0%
Turbidity (NTUs)	1	178	11	9	1	46	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	177	312	321	157	496	-----	-----	-----
Secchi Depth (in.)	1	15	40	41	27	52	-----	-----	-----
Alkalinity, Total (mg/l)	7	30	152	154	133	163	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	30	3.8	3.6	1.8	6.1	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	30	12	12	n.d.	19	-----	-----	-----
Chloride (mg/l)	1	20	12	12	10	13	438(3,6), 250(3,8)	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	154	23*	20	1	69	10(10)	124	81%
Chlorophyll *a* (ug/l) – Lab Determined	1	15	21*	19	1	53	10(10)	12	80%
Color (S.U. - APHA)	1	20	8	8	4	19	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	30	465	457	386	578	1,750(3,6), 1,000(3,8), 3,500(5,6), 2,000(5,8)	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	30	-----	0.02	n.d.	0.22	3.2 (1,6,9), 0.66(1,8,9)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	30	0.6	0.5	0.2	1.6	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	30	-----	n.d.	n.d.	0.30	10(3,6), 100(4,6)	0	0%
Nitrogen, Total (mg/l)	0.1	30	0.7	0.6	0.2	1.7	1(10)	3	10%
Phosphorus, Dissolved (mg/l)	0.02	30	-----	0.02	n.d.	0.05	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	30	0.045	0.04	n.d.	0.12	0.05(10)	11	37%
Phosphorus-Ortho, Dissolved (mg/l)	0.02	30	-----	0.02	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	30	200	199	177	235	875(3,6), 500(3,8)	0	0%
Suspended Solids, Total (mg/l)	4	30	-----	7	n.d.	82	158(1,6), 90(1,8)	0	0%
Microcystin, Total (ug/l)	0.2	15	-----	n.d.	n.d.	14	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, Oxidation-Reduction Potential, Turbidity, Chlorophyll a (Field Probe), and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) 30-day average criterion (monitoring results not directly comparable to criterion).
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (10) Nutrient criteria – Lewis and Clark Lake has been assigned the following nutrient criteria by Nebraska for 2010 Section 303(d) and 305(b) assessment: Chlorophyll a = 10 ug/l, Total Nitrogen = 1 mg/l, and Total Phosphorus = 50 ug/l.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

(F) According to South Dakota's beneficial use support decision criteria, dissolved oxygen levels are not considered impaired if a region exists in the depth profile (i.e., epilimnion) where the dissolved oxygen levels are ≥5 mg/l. Nebraska's dissolved oxygen criteria do not apply to the hypolimnion.

* The highlighted mean values indicate use impairment based on State of Nebraska 2010 Section 303(d) impairment assessment criteria.

Table 5-2. Summary of monthly (June through September) water quality conditions monitored in Lewis and Clark Lake near the Weigand Recreation Area (site GPTLK0815DW) during the 3-year period 2008 through 2010.

Parameter	Monitoring Results(A)						Water Quality Standards Attainment		
	Detection Limit(B)	No. of Obs.	Mean(C)	Median	Min.	Max.	State WQS Criteria(D)	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	13	1206.5	1206.4	1205.5	1207.5	-----	-----	-----
Water Temperature (°C)	0.1	127	21.5	22.0	14.1	25.6	27(1,2,6), 29(1,2,6)	0	0%
Dissolved Oxygen (mg/l)	0.1	127	8.3	8.3	5.5	10.2	5(1,7)	0	0%
Dissolved Oxygen (% Sat.)	0.1	127	97.1	97.5	67.2	121.0	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)(E)	0.1	127	8.3	8.3	5.5	10.2	5(1,7)	0	0%
Hypolimnion Dissolved Oxygen (mg/l)(E)	0.1	0	-----	-----	-----	-----	5(1,7)	-----	-----
Specific Conductance (umhos/cm)	1	127	710	706	658	761	-----	-----	-----
pH (S.U.)	0.1	127	8.4	8.4	7.8	8.9	6.5(1,3,7), 9.0(1,3,6), 9.5(5,6)	0	0%
Turbidity (NTUs)	1	127	23	20	3	94	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	127	312	331	167	439	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	106	23*	17	1	85	10(8)	86	81%
Secchi Depth (in)	1	13	22	20	13	38	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, Oxidation-Reduction Potential, Turbidity, Chlorophyll a (Field Probe), and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) Nutrient criteria – Lewis and Clark Lake has been assigned the following nutrient criteria by Nebraska for 2010 Section 303(d) and 305(b) assessment: Chlorophyll a = 10 ug/l, Total Nitrogen = 1 mg/l, and Total Phosphorus = 50 ug/l.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

(F) Depth-profiles did not indicate the presence of a hypolimnion during monitored period. It is assumed that the water column experienced complete mixing due to shallower water depths during the monitored period.

* The highlighted mean value indicates use impairment based on State of Nebraska 2010 Section 303(d) impairment assessment criteria.

Table 5-3. Summary of monthly (May through September) water quality conditions monitored in Lewis and Clark Lake near the Bloomfield Recreation Area (Site GPTLK0819DW) during the 3-year period 2008 through 2010.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	13	1206.5	1206.4	1205.5	1207.5	-----	-----	-----
Water Temperature (°C)	0.1	101	21.1	22.1	10.2	26.9	27[1,2,6], 29[1,2,6]	0	0%
Dissolved Oxygen (mg/l)	0.1	101	8.8	8.6	5.1	13.3	5[1,7]	0	0%
Dissolved Oxygen (% Sat.)	0.1	101	102.4	101.6	58.9	156.2	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	98	8.9	8.6	6.4	13.3	5[1,7]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	3	6.0	5.9	5.1	7.0	5[1,7]	0	0%
Specific Conductance (umhos/cm)	1	101	714	711	636	775	2,000[4]	0	0%
pH (S.U.)	0.1	101	8.4	8.4	7.8	8.8	6.5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Turbidity (NTUs)	1	94	25	22	2	123	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	101	326	339	190	456	-----	-----	-----
Secchi Depth (in.)	1	13	22	18	16	40	-----	-----	-----
Alkalinity, Total (mg/l)	7	26	152	153	134	164	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	26	5.4	3.3	2.4	39.5	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	26	14	13	6	29	-----	-----	-----
Chloride (mg/l)	1	18	12	12	8	14	438[3,6], 250[3,8]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	78	28*	23	7	138	10[10]	67	86%
Chlorophyll *a* (ug/l) – Lab Determined	1	13	25*	18	8	76	10[10]	12	92%
Color (S.U. - APHA)	1	17	8	8	4	15	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	26	466	457	380	568	1,750[3,6], 1,000[3,8], 3,500[5,6], 2,000[5,8]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	26	-----	0.02	n.d.	0.18	3.9 [1,6,9], 0.75[1,8,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	26	0.6	0.6	0.2	1.5	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	26	-----	0.05	n.d.	0.50	10[3,6], 100[4,6]	0	0%
Nitrogen, Total (mg/l)	0.1	26	0.8	0.7	0.2	1.8	1[10]	6	28%
Phosphorus, Dissolved (mg/l)	0.02	25	-----	0.02	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	26	0.06*	0.06	0.02	0.15	0.05[10]	15	58%
Phosphorus-Ortho, Dissolved (mg/l)	0.02	26	-----	n.d.	n.d.	0.07	-----	-----	-----
Sulfate (mg/l)	1	26	204	203	172	233	875[3,6], 500[3,8]	0	0%
Suspended Solids, Total (mg/l)	4	26	15	17	n.d.	39	158[1,6], 90[1,8]	0	0%
Microcystin, Total (ug/l)	0.2	13	-----	n.d.	n.d.	0.2	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, Oxidation-Reduction Potential, Turbidity, Chlorophyll a (Field Probe), and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) 30-day average criterion (monitoring results not directly comparable to criterion).
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (10) Nutrient criteria – Lewis and Clark Lake has been assigned the following nutrient criteria by Nebraska for 2010 Section 303(d) and 305(b) assessment: Chlorophyll a = 10 ug/l, Total Nitrogen = 1 mg/l, and Total Phosphorus = 50 ug/l.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

* The highlighted mean values indicate use impairment based on State of Nebraska 2010 Section 303(d) impairment assessment criteria.

Table 5-4. Summary of monthly (June through September) water quality conditions monitored in Lewis and Clark Lake near the Devils Nest Area (site GPTLK0822DW) during the 3-year period 2008 through 2010.

Parameter	Monitoring Results(A)						Water Quality Standards Attainment		
	Detection Limit(B)	No. of Obs.	Mean(C)	Median	Min.	Max.	State WQS Criteria(D)	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	14	1206.5	1206.5	1205.5	1207.5	-----	-----	-----
Water Temperature (°C)	0.1	80	20.9	21.9	10.0	26.4	27(1,2,6), 29(1,2,6)	0	0%
Dissolved Oxygen (mg/l)	0.1	80	8.8	8.6	5.7	13.6	5(1,7)	0	0%
Dissolved Oxygen (% Sat.)	0.1	80	101.3	100.3	69.8	138.2	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)(E)	0.1	80	101.3	100.3	69.8	138.2	5(1,7)	0	0%
Hypolimnion Dissolved Oxygen (mg/l)(E)	0.1	0	-----	-----	-----	-----	5(1,7)	-----	-----
Specific Conductance (umhos/cm)	1	80	718	720	647	769	-----	-----	-----
pH (S.U.)	0.1	80	8.3	8.3	7.9	8.7	6.5(1,3,7), 9.0(1,3,6), 9.5(5,6)	0	0%
Turbidity (NTUs)	1	72	25	20	5	83	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	80	329	340	183	445	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	62	29*	26	4	81	10(8)	50	81%
Secchi Depth (in)	1	14	20	18	12	33	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, Oxidation-Reduction Potential, Turbidity, Chlorophyll a (Field Probe), and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).

(2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.

(3) Criteria for the protection of domestic water supply waters.

(4) Criteria for the protection of agricultural water supply waters.

(5) Criteria for the protection of commerce and industry waters.

(6) Daily maximum criterion (monitoring results directly comparable to criterion).

(7) Daily minimum criterion (monitoring results directly comparable to criterion).

(8) Nutrient criteria – Lewis and Clark Lake has been assigned the following nutrient criteria by Nebraska for 2010 Section 303(d) and 305(b) assessment: Chlorophyll a = 10 ug/l, Total Nitrogen = 1 mg/l, and Total Phosphorus = 50 ug/l.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

(F) Depth-profiles did not indicate the presence of a hypolimnion during monitored period. It is assumed that the water column experienced complete mixing due to shallower water depths during the monitored period.

* The highlighted mean value indicates use impairment based on State of Nebraska 2010 Section 303(d) impairment assessment criteria.

Table 5-5. Summary of monthly (May through September) water quality conditions monitored in Lewis and Clark Lake near the Charley Creek Area (Site GPTLK0825DW) during the 3-year period 2008 through 2010.

Parameter	Monitoring Results(A)						Water Quality Standards Attainment		
	Detection Limit(B)	No. of Obs.	Mean(C)	Median	Min.	Max.	State WQS Criteria(D)	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	14	1206.5	1206.5	1205.5	1207.5	-----	-----	-----
Water Temperature (°C)	0.1	55	20.7	21.7	14.0	26.1	27(1,2,6), 29(1,2,6)	0	0%
Dissolved Oxygen (mg/l)	0.1	55	8.6	8.2	6.2	12.2	5(1,7)	0	0%
Dissolved Oxygen (% Sat.)	0.1	55	99.3	95.2	79.4	128.1	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)(E)	0.1	55	8.6	8.2	6.2	12.2	5(1,7)	0	0%
Hypolimnion Dissolved Oxygen (mg/l)(E)	0.1	0	-----	-----	-----	-----	5(1,7)	-----	-----
Specific Conductance (umhos/cm)	1	55	691	686	609	738	2,000(4)	0	0%
pH (S.U.)	0.1	55	8.3	8.3	8.0	8.5	6.5(1,3,7), 9.0(1,3,6), 9.5(5,6)	0	0%
Turbidity (NTUs)	1	50	38	37	11	91	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	55	332	356	203	436	-----	-----	-----
Secchi Depth (in.)	1	14	15	14	9	24	-----	-----	-----
Alkalinity, Total (mg/l)	7	13	153	154	135	172	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	13	4.2	3.9	1.8	8.3	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	13	13	13	8	23	-----	-----	-----
Chloride (mg/l)	1	9	12	11	11	14	438(3,6), 250(3,8)	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	46	26*	22	8	50	8(10)	34	100%
Chlorophyll *a* (ug/l) – Lab Determined	1	13	22*	15	8	46	8(10)	9	100%
Color (S.U. - APHA)	1	8	9	9	n.d.	16	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	13	447	446	380	542	1,750(3,6), 1,000(3,8), 3,500(5,6), 2,000(5,8)	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	13	-----	n.d.	n.d.	0.09	3.9 (1,6,9), 0.77(1,8,9)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	13	0.7	0.6	0.2	1.4	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	13	-----	0.15	n.d.	0.42	10(3,6), 100(4,6)	0	0%
Nitrogen, Total (mg/l)	0.1	13	0.8	0.7	0.4	1.5	1(10)	3	23%
Phosphorus, Dissolved (mg/l)	0.02	12	-----	0.02	n.d.	0.07	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	13	0.07*	0.08	n.d.	0.16	0.05(10)	9	69%
Phosphorus-Ortho, Dissolved (mg/l)	0.02	13	-----	n.d.	n.d.	0.05	-----	-----	-----
Sulfate (mg/l)	1	13	192	189	175	217	875(3,6), 500(3,8)	0	0%
Suspended Solids, Total (mg/l)	4	13	27	27	6	52	158(1,6), 90(1,8)	0	0%
THM Formation Potential, Total	4	9	224	156	74	561	-----	-----	-----
Microcystin, Total (ug/l)	0.2	13	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, Oxidation-Reduction Potential, Turbidity, Chlorophyll a (Field Probe), and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) 30-day average criterion (monitoring results not directly comparable to criterion).
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (10) Nutrient criteria – Lewis and Clark Lake has been assigned the following nutrient criteria by Nebraska for 2010 Section 303(d) and 305(b) assessment: Chlorophyll a = 10 ug/l, Total Nitrogen = 1 mg/l, and Total Phosphorus = 50 ug/l.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

(F) Depth-profiles did not indicate the presence of a hypolimnion during monitored period. It is assumed that the water column experienced complete mixing due to shallower water depths during the monitored period.

* The highlighted mean values indicate use impairment based on State of Nebraska 2010 Section 303(d) impairment assessment criteria.

5.1.2.2 Spatial Variation

Monthly (i.e., June, July, August, and September) longitudinal temperature contour plots of Lewis and Clark Lake were constructed for the 3-year period 2008 through 2010 (Plate 1 - Plate 12). The longitudinal temperature contour plots were developed from the temperature depth-profiles measured at the reservoir monitoring sites along the submerged old Missouri River channel. The contour plots show longitudinal variation, of varying magnitude, in Lewis and Clark Lake water temperatures from the dam to the reservoir's upper reaches during the June through September period. Significant vertical variation (i.e., more than 5º C) in Lewis and Clark Lake water temperatures was not observed during the 3-year period. This is attributed to the polymixic nature of the reservoir.

5.1.2.3 Summer Thermal Stratification

Although some summer thermal stratification of Lewis and Clark Lake can occur, the relative shallowness, short retention time, and bottom withdrawal of the reservoir seemingly inhibit the formation of a strong thermocline and long-lasting stratification during the summer.

5.1.3 DISSOLVED OXYGEN

Monthly (i.e., June, July, August, and September) longitudinal dissolved oxygen contour plots of Lewis and Clark Lake were constructed for the 3-year period 2008 through 2010 (Plate 13 - Plate 24). The longitudinal dissolved oxygen contour plots were developed from dissolved oxygen depth-profiles measured at the reservoir monitoring sites along the submerged old Missouri River channel. The contour plots show that the dissolved oxygen levels varied longitudinally from the dam to reservoir's upper reaches and vertically from the reservoir surface to the bottom. Monitoring during the 3-year period indicated that an area of low dissolved oxygen (<5 mg/l) developed in the area near the dam in August 2008 (Plate 15), July 2009 (Plate 18), September 2009 (Plate 20), and July 2010 (Plate 22). The area of low dissolved oxygen occurred along the reservoir bottom when thermal stratification inhibited mixing long enough for degradation of dissolved oxygen levels. The area of low dissolved oxygen is seemingly periodic, and dissipates when conditions allow for complete mixing of the water column.

5.1.4 WATER CLARITY

5.1.4.1 Secchi Transparency

Figure 5-1 displays a box plot of the Secchi depth transparencies measured along Lewis and Clark Lake during the 3-year period 2008 through 2010. The measurements were taken at the five reservoir monitoring sites (i.e., GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW). Secchi depth transparency increased in a downstream direction from the upper reaches of the reservoir to near the dam. This is attributed to suspended sediment in the inflowing Niobrara and Missouri Rivers settling out in the reservoir as current velocities slow. The surface waters near Gavins Point Dam are significantly clearer than the upstream regions of the reservoir.

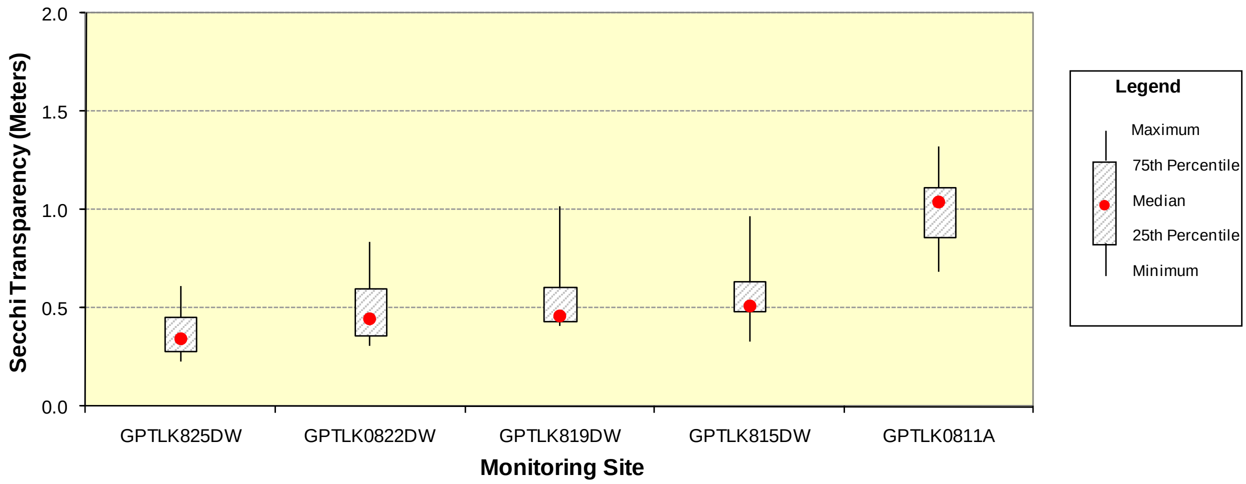

Figure 5-1. Box plot of Secchi depth transparencies measured in Lewis and Clark Lake during the 3-year period 2008 through 2010.

5.1.4.2 Turbidity

Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted with no change in direction or flux level. Turbidity in water is caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. Monthly (i.e., June, July, August, and September) longitudinal turbidity contour plots of Lewis and Clark Lake were constructed for the 3-year period 2008 through 2010 (Plate 25 - Plate 36). The turbidity contour plots were developed from the turbidity depth-profiles measured at the reservoir monitoring sites along the submerged old Missouri River channel. The contour plots show that turbidity levels in Lewis and Clark Lake vary longitudinally and vertically. As seen in the contour plots, turbidity levels measured in Lewis and Clark Lake during the 3-year period varied longitudinally from the dam to the reservoir's upstream reaches. This is attributed to the turbid conditions of the inflowing Missouri River, and wave-action that re-suspends deposited sediment in the shallow delta area in the upstream reaches of Lewis and Clark Lake.

5.1.5 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Paired near-surface and near-bottom water quality samples collected from Lewis and Clark Lake during the summer were compared. Near-surface conditions were represented by samples collected at ½ the measured Secchi depth, and near-bottom conditions were represented by samples collected within 1-meter of the reservoir bottom. The compared samples were collected at the near-dam site GPTLK0811A during the 3-year period 2008 through 2010. During the period a total of 12 paired samples were collected monthly from June through September. Box plots were constructed to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential (ORP), pH, alkalinity, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), total ammonia, and total phosphorus (Figure 5-2). A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were significantly different for all assessed parameters except TOC, TKN, and total ammonia. Parameters that were significantly lower in the near-bottom water of Lewis and Clark Lake included: water temperature ($p < 0.01$), dissolved oxygen ($p < 0.001$), and pH ($p < 0.001$). Parameters that were significantly higher in the near-bottom water included: ORP ($p < 0.001$), alkalinity ($p < 0.05$), and total phosphorus ($p < 0.01$).

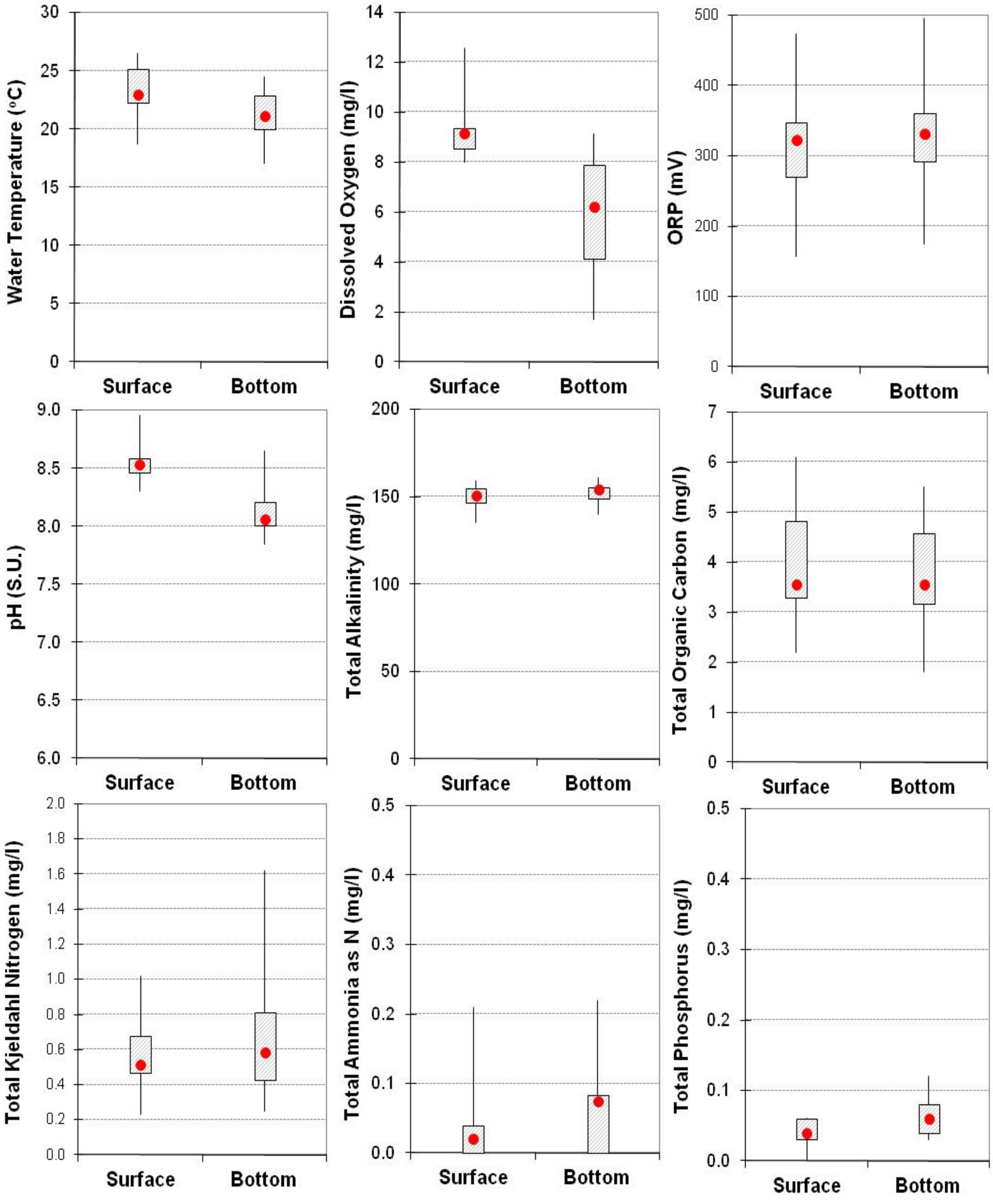

Figure 5-2. Box plots comparing surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential, pH, alkalinity, total organic carbon, total Kjeldahl nitrogen, total ammonia nitrogen, and total phosphorus monitored in Lewis and Clark Lake during the summer at site GPTLK0811A over the 3-year period 2008 through 201.
(Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

5.1.6 Reservoir Trophic Status

Trophic State Index (TSI) values for Lewis and Clark Lake were calculated from monitoring data collected during the 3-year period 2008 through 2010 (Table 5-6). The calculated TSI values indicate that the area near the dam (i.e., site GPTLK0811A) is eutrophic, the middle and upper reaches of the reservoir (i.e., sites GPTLK0819DW and GTPLK0825DW) are eutrophic to hypereutrophic.

Table 5-6. Mean Trophic State Index (TSI) values calculated for Lewis and Clark Lake. TSI values are based on monitoring at the identified three sites during the 3-year period 2008 through 2010.

Monitoring Site	Mean – TSI (Secchi Depth)	Mean – TSI (Total Phos.)	Mean – TSI (Chlorophyll)	Mean – TSI (Average)
GPTLK0811A	60	53	67	60
GPTLK0819DW	69	57	69	65
GPTLK0825DW	76	59	68	67

Note: See Section 4.1.4 for discussion of TSI calculation.

5.1.7 Phytoplankton Community

5.1.7.1 Phytoplankton

Phytoplankton grab samples collected from Lewis and Clark Lake at sites GPTLK0811A, GPTLK0819DW, and GPTLK0825DW during the spring and summer over the 3-year period 2008 through 2010 are summarized in Table 5-7, Table 5-8, and Table 5-9. The following seven taxonomic divisions were represented by taxa collected in the phytoplankton samples: Bacillariophyta (Diatoms), Chlorophyta (Green Algae), Chrysophyta (Golden Algae), Cryptophyta (Cryptomonad Algae), Cyanobacteria (Blue-Green Algae), Pyrrophyta (Dinoflagellate Algae), and Euglenophyta (Euglenoid Algae). The relative abundance of phytoplankton in samples collected from Lewis and Clark Lake in May, July, and September 2010, based on biovolume, is shown in Figure 5-3. Diatoms (Bacillariophyta) are the most dominant phytoplankton group present in Lewis and Clark Lake. Major phytoplankton genera sampled in Lewis and Clark Lake during 2010 (i.e., genera comprising more than 10% of the total biovolume of at least one sample) included the Bacillariophyta *Asterionella, Aulacoseria, Cyclotella, and Fragilaria*; the Chlorophyta Chlamydomonas; and the Cryptophyta *Cryptomonas*. On one occasion (i.e., May 2008) an elevated level (14 ug/l) of the cyanobacteria toxin microcystin was monitored at site GPTLK0811A (Table 5-1). Other than this one occasion, no levels of microcystin above 1 ug/l were monitored at sites GPTLK0811A, GPTLK0818DW, or GPTLK0825DW during the 3-year period 2008 through 2010.

5.1.7.2 Zooplankton

Zooplankton vertical-tow samples were collected from Lewis and Clark Lake at sites GPTLK0811A, GPTLK0819DW, and GPTLK0825DW in May, July, and September of 2010 (Table 5-10). The sampled zooplankton included four taxonomic groupings: Cladocerans, Copepods, Rotifers, and Ostracods. The relative abundance of these four taxonomic grouping in the zooplankton samples collected in 2010 is shown in Figure 5-4. Copepods were most abundant, followed by Cladocerans and rotifers. Only a few Ostracods were sampled in September at sites GPTLK0819DW and GPTLK0825DW. Major zooplankton species sampled in Lewis and Clark Lake during 2010 (i.e., species comprising more than 10% of the total biomass of at least one sample) included Cladocerans *Ceriodaphnia spp., Daphnia galeata, Daphnia retrocurva,* and *Diaphanosoma brachyurun*; Copepods *Acanthocyclops vernalis, Calanoid copepodid, Cyclopoid copepodid, Diacyclops, thomasi, Leptodiaptomus siciloides, Mesocyclops edax,* and *Tropocyclops prasinus*; and Rotifers *Brachionus calyciflorus, Keratella quadrata, Polyarthra vulgaris,* and *Synchaeta spp.* Dominant species (i.e., species comprising more than 25% of the total biomass of at least one sample) included Cladocerans *Daphnia retrocurva*; Copepods *Calanoid copepodid, Cyclopoid copepodid,* and *Mesocyclops edax.*

Table 5-7. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected at the near-dam area of Lewis and Clark Lake (i.e., site GPTLK0811A) during the 3-year period 2008 through 2010.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.
May 2008	1.9957	13	1.00	3	<0.01	1	<0.01	1	<0.01	0	-----	0	-----	1	<0.01
Jun 2008	0.0013	9	0.70	10	0.17	1	<0.01	1	0.13	1	<0.01	1	<0.01	0	-----
Jul 2008	0.0019	23	0.98	12	0.01	3	<0.01	1	<0.01	6	<0.01	1	<0.01	1	<0.01
Aug 2008	0.7722	6	0.88	11	0.01	2	<0.01	1	0.08	4	0.02	1	<0.01	2	0.01
Sep 2008	0.6705	10	0.92	19	0.02	0	<0.01	2	0.05	4	<0.01	2	<0.01	1	<0.01
May 2009	23.7660	19	0.93	8	0.02	2	<0.01	2	0.05	1	<0.01	1	<0.01	1	<0.01
Jun 2009	0.0021	9	0.99	11	0.01	0	-----	0	-----	1	<0.01	0	-----	1	<0.01
Jul 2009	2.2125	13	0.91	9	0.04	0	-----	1	0.05	0	-----	1	<0.01	1	<0.01
Aug 2009	1.0469	9	0.35	8	0.09	2	0.05	1	0.18	5	0.05	2	0.27	0	-----
Sep 2009	1.6888	10	0.24	7	0.09	1	0.04	1	0.52	7	0.08	2	0.03	2	<0.01
May 2010	3.3778	15	0.97	7	0.02	2	<0.01	1	0.01	0	-----	0	-----	0	-----
Jul 2010	0.2769	10	0.77	16	0.09	0	-----	2	0.12	3	0.02	0	-----	1	<0.01
Sep 2010	0.9476	6	0.95	17	0.01	0	-----	2	0.02	7	0.02	3	0.01	1	<0.01
Mean	**2.8277**	**11.7**	**0.81**	**10.6**	**0.04**	**1.1**	**0.01**	**1.2**	**0.10**	**3.0**	**0.02**	**1.1**	**0.04**	**0.9**	**<0.01**

* Mean percent composition represents the mean when taxa of that division are present.

Table 5-8. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected from the middle reaches of Lewis and Clark Lake (i.e., site GPTLK0819DW) during the 3-year period 2008 through 2010.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.
Jun 2008	0.0021	10	0.58	15	0.10	2	<0.01	1	0.30	2	0.02	1	<0.01	1	<0.01
Jul 2008	0.0009	10	0.86	15	0.06	1	<0.01	1	0.05	4	<0.01	1	0.01	2	0.01
Aug 2008	0.2888	7	0.77	10	0.06	1	<0.01	1	0.15	2	<0.01	1	0.01	1	0.01
Sep 2008	0.3856	11	0.92	14	0.05	0	-----	1	<0.01	3	0.01	3	0.02	1	<0.01
May 2009	8.8087	17	0.73	9	0.04	1	<0.01	2	0.23	0	-----	0	-----	0	-----
Jun 2009	2.0366	29	0.92	7	0.08	1	<0.01	1	<0.01	0	-----	0	-----	0	-----
Jul 2009	1.1121	15	0.68	10	0.15	0	-----	1	0.16	1	<0.01	1	<0.01	1	0.01
Aug 2009	0.3067	12	0.57	11	0.15	1	0.13	1	0.09	5	0.06	1	<0.01	0	-----
Sep 2009	2.2394	21	0.67	12	0.08	1	<0.01	2	0.20	3	0.04	0	-----	3	<0.01
Jul 2010	0.2207	6	0.22	10	0.19	1	<0.01	1	0.44	2	0.02	1	0.03	1	0.09
Sep 2010	1.0848	15	0.98	14	<0.01	0	-----	2	0.01	3	0.01	0	-----	1	<0.01
Mean	**1.4988**	**13.9**	**0.72**	**11.5**	**0.09**	**0.8**	**0.02**	**1.3**	**0.15**	**2.3**	**0.02**	**0.8**	**0.01**	**1.0**	**0.02**

* Mean percent composition represents the mean when taxa of that division are present.

Table 5-9. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected from the upper reaches of Lewis and Clark Lake (i.e., site GPTLK0825DW) during the 3-year period 2008 through 2010.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.
Jun 2008	0.0008	19	0.68	16	0.12	3	0.02	1	0.16	2	<0.01	1	<0.01	1	<0.01
Jul 2008	0.0004	17	0.62	12	0.15	1	<0.01	1	0.23	4	<0.01	0	-----	0	-----
Aug 2008	0.1136	13	0.67	5	0.07	0	-----	1	0.24	1	<0.01	0	-----	1	0.02
Sep 2008	0.5900	10	0.70	16	0.13	0	-----	2	0.14	4	<0.01	2	0.03	1	<0.01
May 2009	2.2203	30	0.88	9	0.04	1	<0.01	2	0.08	0	-----	0	-----	0	-----
Jun 2009	4.0218	31	0.62	7	0.38	0	-----	0	-----	0	-----	1	<0.01	0	-----
Jul 2009	1.7597	27	0.91	6	0.02	0	-----	2	0.06	0	-----	2	0.01	2	<0.01
Aug 2009	1.2769	19	0.67	14	0.20	0	-----	1	0.11	3	<0.01	1	0.02	1	<0.01
Sep 2009	1.0819	25	0.60	11	0.12	0	-----	1	0.20	5	0.06	0	-----	1	0.02
Jul 2010	0.1957	11	0.60	23	0.37	0	-----	1	0.01	1	<0.01	1	0.02	1	<0.01
Sep 2010	0.6673	20	0.97	13	0.02	0	-----	0	-----	1	0.01	1	<0.01	1	<0.01
Mean	**1.0844**	**21.2**	**0.71**	**10.7**	**0.14**	**0.6**	**0.01**	**1.2**	**0.15**	**2.1**	**0.01**	**0.8**	**0.01**	**0.8**	**0.01**

* Mean percent composition represents the mean when taxa of that division are present.

Table 5-10. Estimated biomass, number of species, and percent composition (based on biomass) by taxonomic grouping for zooplankton tow samples collected in Lewis and Clark Lake at Sites GPTLK0811A, GPTLK0819DW, and GPTLK0825DW during 2010.

Date	Estimated Biomass (µg/L dry wt.)	Cladocerans		Copepods		Rotifers		Ostracod	
		No. of Species	Percent Comp.	No. of Species	Percent Comp.	No. of Species	Percent Comp.	No. of Species	Percent Comp.
Site GPTLK08110A – Near Dam									
May 2010	32.281	2	0.19	3	0.47	9	0.34	-----	-----
July 2010	33.029	3	0.19	6	0.60	12	0.21	-----	-----
Sept 2010	10.012	2	0.27	4	0.66	8	0.07	-----	-----
Mean	**25.107**	**2.3**	**0.22**	**4.3**	**0.58**	**9.7**	**0.21**	-----	-----
Site GPTLK0819DW – Bloomfield Recreation Area									
May 2010	No Data								
July 2010	1.910	1	0.03	4	0.77	15	0.20	-----	-----
Sept 2010	1.951	7	0.37	7	0.58	9	0.03	1	0.02
Mean	**1.931**	**4.0**	**0.20**	**5.5**	**0.68**	**12.0**	**0.12**	-----	-----
Site GPTLK0825DW – Charley Creek									
May 2010	No Data								
July 2010	1.448	2	0.33	3	0.47	11	0.20	-----	-----
Sep 2010	4.091	5	0.27	6	0.72	6	0.01	1	<0.01
Mean	**2.770**	**3.5**	**0.30**	**4.5**	**0.60**	**8.5**	**0.11**	-----	-----

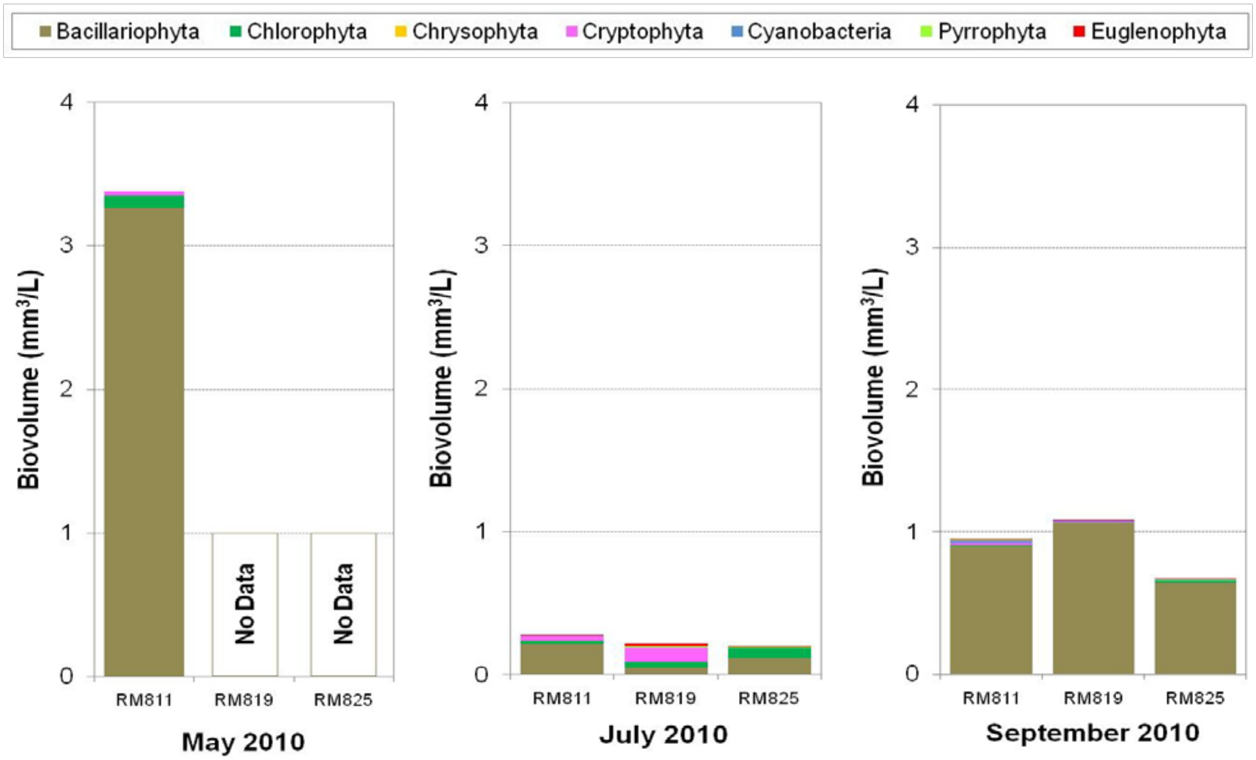

Figure 5-3. Relative abundance of phytoplankton in samples collected from Lewis and Clark Lake during 2010.

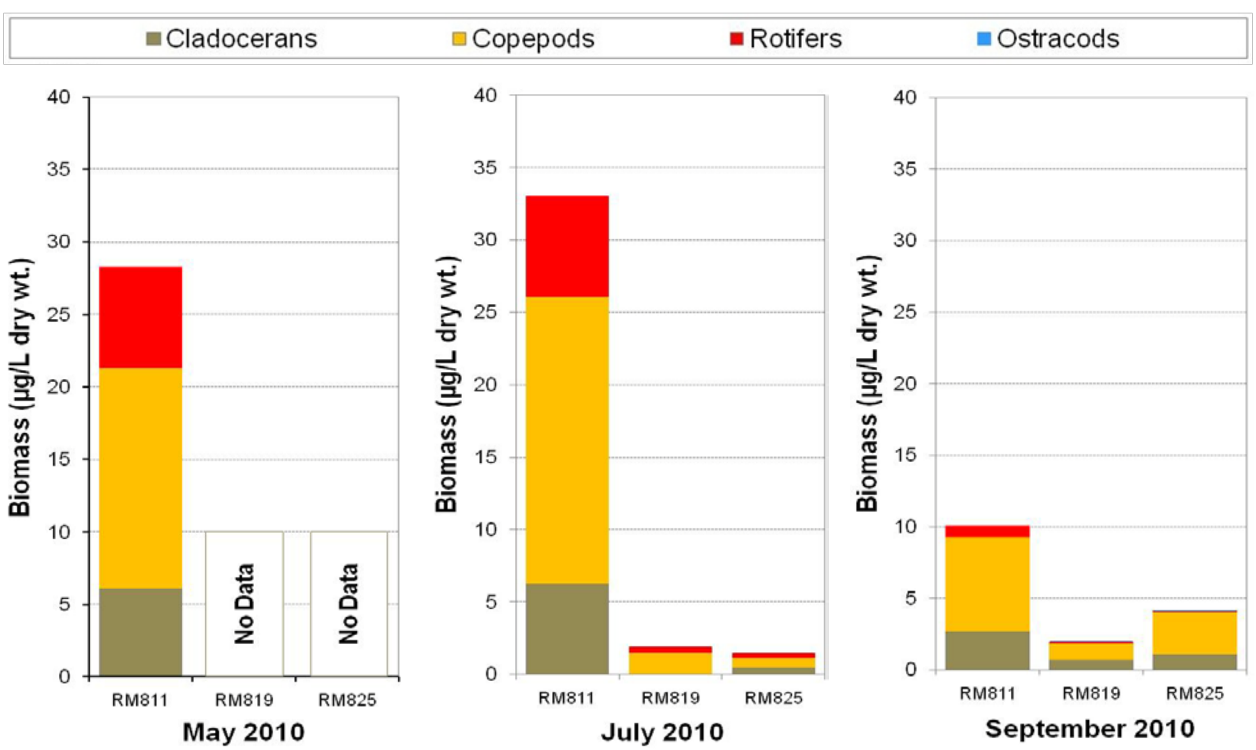

Figure 5-4. Relative abundance of zooplankton in samples collected from Lewis and Clark Lake during 2010.

5.1.8 BACTERIA MONITORING AT SWIMMING BEACHES ON LEWIS AND CLARK LAKE

During the 3-year period 2008 through 2010, bacteria samples were collected weekly from May through September at five swimming beaches located on Lewis and Clark Lake. The five swimming beaches where the bacteria samples were collected were: Weigand Recreation Area (site GPTLKBACT5), Gavins Point Recreation Area (site GPTLKBACT4), Lewis and Clark Recreation Area – Midway West Beach (site GPTLKBACT3) and Midway East Beach (GPTLKBACT2), and the Marina Sailing Boat Area (site GPTLKBACT1) (Figure 3-1). Table 5-11 summarizes the results of the bacteria sampling. The geometric means were calculated as running geometric means for five consecutive weekly bacteria samples and nondetects were set to 1. The bacteria sampling results were compared to the following bacteria criteria for support of "full-body contact" recreation:

<u>Fecal Coliform:</u>
Bacteria of the fecal coliform group should not exceed a geometric mean of 200/100ml, nor equal or exceed 400/100ml, in more than 10% of the samples. These criteria are based on a minimum of five samples taken within a 30-day period.

<u>*E. coli*:</u>
E. coli bacteria should not exceed a geometric mean of 126/100ml. For increased confidence of the criteria, the geometric mean should be based on a minimum of five samples taken within a 30-day period. Single sample maximum allowable density for designated bathing beaches is 235/100ml.

Nebraska's recreational impairment assessment methodology (Section 4.4.1.1.2) defines criteria for "seasonal geomeans" for fecal coliform and *E. coli* bacteria. The calculated seasonal fecal coliform geomeans at GPTLKBACT5 for 2008, 2009, and 2010 are, respectively, 45, 12, and 25 cfu/100ml. The calculated seasonal *E. coli* geomeans at GPTLKBACT5 for 2008, 2009, and 2010 are, respectively, 37, 12, and 46. Based on these criteria, recreation was fully supported at the Nebraska swimming beach on Lewis and Clark Lake during the 3-year period 2008 through 2010. It is noted that 17 percent of calculated *E. coli* geomeans at site GPTLKBACT5 exceeded the geometric mean criteria of 126/100ml (Table 5-11).

5.1.9 IMPAIRMENT OF DESIGNATED WATER QUALITY BENEFICIAL USES

Based on the State of Nebraska's impairment assessment methodology (Section 4.4.1), the water quality conditions monitored in Lewis and Clark Lake (i.e., chlorophyll *a* and total phosphorus) during the 3-year period 2008 through 2010 indicate impairment of aquatic life due to nutrients (Table 5-1, Table 5-2, Table 5-3, Table 5-4, and Table 5-5). It is also noted that the estimated loss of 24.3 percent of the "as-built" multi-purpose pool volume of Lewis and Clark Lake (Table 1-1) is approaching Nebraska's impairment identification criteria of 25 percent volume loss.

Table 5-11. Summary of weekly (May through September) bacteria sampling conducted at five swimming beaches on Lewis and Clark Lake over the 3-year period 2008 through 2010.

	Weigand Recreation Area (GPTLKBACT5)	Gavins Point Recreation Area (GPTLKBACT4)	Lewis & Clark Rec. Area Midway West (GPTLKBACT3)	Lewis & Clark Rec. Area Midway East (GPTLKBACT2)	Marina Sailing Boat Area (GPTLKBACT1)
Fecal Coliform Bacteria (cfu/100ml):					
Number of Samples	66	66	66	65	66
Mean	197	35	36	53	36
Median	18	12	4	8	4
Minimum	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum	5,460	510	640	990	440
Percent of samples exceeding 400/100ml	9%	2%	3%	2%	2%
• **Geometric Mean**					
Number of Geomeans	54	54	54	54	54
Average	66	15	8	13	12
Median	23	12	4	9	5
Minimum	3	3	1	2	1
Maximum	682	48	30	37	129
Percent of Geomeans exceeding 200/100ml	7%	0%	0%	0%	0%
***E. coli* Bacteria (MPN/100ml)**					
Number of Samples	66	66	66	66	66
Mean	266	43	35	59	61
Median	23	12	4	6	6
Minimum	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum	5,200	921	770	960	1,842
Percent of samples exceeding 235/100ml	21%	5%	3%	6%	5%
• **Geomean**					
Number of Geomeans	54	54	54	54	54
Average	69	15	7	16	11
Median	26	11	5	7	5
Minimum	3	3	n.d.	2.	2
Maximum	595	54	24	76	65
Percent of Geomeans exceeding 126/100ml	17%	0%	0%	0%	0%

n.d. = Not detected.
Note: Not detected values set to 1 to calculate mean and geometric mean.

6 WATER QUALITY CONDITIONS OF INFLOWS TO LEWIS AND CLARK LAKE

6.1 NIOBRARA RIVER

6.1.1 STATISTICAL SUMMARY AND COMPARISON TO APPLICABLE WATER QUALITY STANDARDS CRITERIA

The water quality conditions that were monitored in the Niobrara River at site GPTNFNIOR1 (Figure 3-1) during the 3-year period 2008 through 2010 are summarized in Table 6-1. A review of these results indicated no significant water quality concerns.

6.1.2 NUTRIENT FLUX CONDITIONS

Nutrient flux rates of the Niobrara River, near the river's confluence with the Missouri River, were calculated based on near-surface water quality samples collected at site GPTNFNIOR1 and the instantaneous flow conditions at the time of sample collection (Table 6-2). It must be recognized that the concentrations of particulate-associated constituents can vary significantly from the river surface to its bottom because of the sinking of particulate matter and its transport nearer the river bottom. Since the instantaneous concentration of particulate-associated constituents (i.e., total phosphorus and total organic carbon) are likely higher nearer the river bottom, near-surface grab samples likely under estimate the "true" water-column composite concentration for these constituents. Thus, the flux rates given for total phosphorus and total organic carbon in Table 6-2 should be considered minimum estimates with the actual flux rates being higher. The maximum nutrient flux rates are attributed to greater nonpoint-source nutrient loadings associated with runoff conditions.

6.1.3 CONTINUOUS WATER TEMPERATURE MONITORING OF THE NIOBRARA RIVER AT USGS GAGE SITE 06465500 NEAR VERDEL, NEBRASKA

Through an agreement with the USGS, a water temperature monitoring probe was added to the USGS's gage (06465500) on the Niobrara River near Verdel, NE (i.e., near site GTPNFNIOR1). Beginning in April 2005, hourly water temperature measurements were recorded at the site. Plate 37, Plate 38, and Plate 39, respectively, plot mean daily water temperature and river discharge determined for 2008, 2009, and 2010.

Table 6-1. Summary of near-surface water quality conditions monitored in the Niobrara River near Niobrara, Nebraska (i.e., site GPTNFNIOR1) during the 3-year period 2008 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Streamflow (cfs)	1	19	2,220	1,950	753	3,950	-----	-----	-----
Water Temperature (°C)	0.1	19	19.3	21.7	0.4	30.8	29[1,2,6]	1	5%
Dissolved Oxygen (mg/l)	0.1	18	9.6	8.9	7.5	14.7	5[1,7]	0	0%
Dissolved Oxygen (% Sat.)	0.1	18	105.5	104.3	91.2	126.0	-----	-----	-----
pH (S.U.)	0.1	18	8.4	8.4	7.5	8.9	6.5[1,7], 9.0[1,6]	0	0%
Specific Conductance (umhos/cm)	1	19	300	298	222	390	2,000[4]	0	0%
Oxidation-Reduction Potential	1	18	342	345	181	491	-----	-----	-----
Alkalinity, Total (mg/l)	7	19	133	132	121	161	-----	0	0%
Carbon, Total Organic (mg/l)	0.05	19	5.3	4.9	1.8	11.6	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	19	22	20	6	38	-----	-----	-----
Chloride (mg/l)	1	14	3	3	2	6	-----	-----	-----
Chlorophyll *a* (ug/l)	1	8	42	32	n.d.	111	-----	-----	-----
Color (S.U. - APHA)	1	13	16	15	6	29	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	19	205	204	138	262	-----	-----	-----
Hardness, Total (mg/l)	1	2	146	146	126	165	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	19	-----	0.02	n.d.	0.26	3.9 [1,8,10], 0.81 [1,8,10]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	19	1.1	1.0	0.4	2.1	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	19	0.66	0.60	n.d.	1.80	10[3,6], 100[4,6]	0	0%
Nitrogen, Total (mg/l)	0.1	19	1.8	1.7	1.1	3.1	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	17	0.05	0.05	n.d.	0.12	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	19	0.27	0.28	0.14	0.55	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	19	-----	0.05	n.d.	0.14	-----	-----	-----
Sulfate (mg/l)	1	19	25	24	15	62	-----	-----	-----
Suspended Solids, Total (mg/l)	4	19	197	173	66	560	-----	-----	-----
Turbidity (NTU)	1	18	151	103	40	491	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	2	-----	84	n.d.	167	750[10], 87[11]	0, 1	0%, 50%
Antimony, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	0.7	88[10], 30[11], 6[12]	0	0%
Arsenic, Dissolved (ug/l)	1	2	5	5	4	6	340[10], 16.7[11], 10[12]	0	0%
Barium, Dissolved (ug/l)	5	2	112	112	111	112	2,000[11]	0	0%
Beryllium, Dissolved (ug/l)	2	2	-----	n.d.	n.d.	n.d.	130[10], 5.3[11], 4[12]	0	0%
Cadmium, Dissolved (ug/l)	0.2	2	-----	n.d.	n.d.	n.d.	8.5[10], 0.32[11], 5[12]	0, 1, 0	0%, 13%, 0%
Chromium, Dissolved (ug/l)	10	2	-----	n.d.	n.d.	n.d.	807[10], 105[11], 100[12]	0	0%
Copper, Dissolved (ug/l)	2	2	-----	n.d.	n.d.	n.d.	19[10], 12[11], 1,000[12]	0	0%
Iron, Dissolved (ug/l)	7	12	-----	20	n.d.	184	1,000[11]	0	0%
Lead, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	97[10], 3.8.2[11], 15[12]	0	0%
Manganese, Dissolved (ug/l)	2	12	-----	n.d.	n.d.	175	-----	-----	-----
Mercury, Dissolved (ug/l)	0.05	2	-----	n.d.	n.d.	n.d.	1.4[10]	0	0%
Mercury, Total (ug/l)	0.05	2	-----	n.d.	n.d.	n.d.	0.77[11], 2[12]	0	0%
Nickel, Dissolved (ug/l)	10	2	-----	n.d.	n.d.	n.d.	645[10], 72[11], 100[12]	0	0%
Selenium, Total (ug/l)	1	2	3	3	3	3	20[4,10], 5[11], 50[12]	0	0%
Silver, Dissolved (ug/l)	1	2	-----	n.d.	n.d.	n.d.	6.6[10], 100[12]	0	0%
Thallium, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	1,400[10], 6.3[11], 2[12]	0	0%
Zinc, Dissolved (ug/l)	5	2	-----	n.d.	n.d.	n.d.	161[10,11], 5,000[12]	0	0%
Acetochlor, Total (ug/l)[D]	0.05	2	-----	n.d.	n.d.	n.d.	-----	-----	-----
Atrazine, Total (ug/l)[D]	0.05	2	-----	0.15	n.d.	0.30	330[10], 12[11], 3[12]	0	0%
Metolachlor, Total (ug/l)[D]	0.05	2	-----	n.d.	n.d.	n.d.	390[10], 100[11]	0	0%
THM Formation Potential, Total	4	7	156	152	98	220	-----	-----	-----
Pesticide Scan (ug/l)[E]	0.05[F]	1	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected.

[A] Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

[B] Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[C] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- [1] Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- [2] Nebraska's temperature criterion is 29°C.
- [3] Criteria for the protection of domestic water supply waters.
- [4] Criteria for the protection of agricultural water supply waters.
- [5] Criteria for the protection of commerce and industry waters.
- [6] Daily maximum criterion (monitoring results directly comparable to criterion).
- [7] Daily minimum criterion (monitoring results directly comparable to criterion).
- [8] 30-day average criterion (monitoring results not directly comparable to criterion).
- [9] Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- [10] Acute (CMC) criterion for the protection of freshwater aquatic life.
- [11] Chronic (CCC) criterion for the protection of freshwater aquatic life.
- [12] Criterion for the protection of human health.

Note: Some of Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

[D] Immunoassay analysis.

[E] The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

[F] Detection limits vary by pesticide – 0.05 ug/l is a median detection limit for the pesticides in the pesticide scan.

Table 6-2. Summary of nutrient flux rates (kg/sec) calculated for the Niobrara River near Niobrara, Nebraska (i.e., site GPTNFNIOR1) for the 3-year period 2008 through 2010.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	19	19	19	19	19	17	19
Mean	2,219	0.0021	0.0758	0.0429	0.0189	0.0035	0.3427
Median	1,950	0.0019	0.0603	0.0297	0.0119	0.0036	0.2789
Minimum	753	n.d.	0.0189	n.d.	0.0043	n.d.	0.0746
Maximum	3,950	0.0106	0.1988	0.1611	0.0511	0.0101	0.8652

Note: Non-detect values set to 0 for flux calculations.

6.2 MISSOURI RIVER BELOW THE CONFLUENCE OF THE NIOBRARA RIVER

6.2.1 STATISTICAL SUMMARY AND COMPARISON TO APPLICABLE WATER QUALITY STANDARDS CRITERIA

The water quality conditions that were monitored in the Missouri River near Running Water, SD at site GPTNFMORR1 (Figure 3-1) during 2009 and 2010 are summarized in Table 6-3. A review of these results indicated no significant water quality concerns.

6.2.2 VERTICAL WATER QUALITY VARIATION IN THE MISSOURI RIVER

Depth discrete water quality monitoring of the Missouri River at site GPTNFMORR1 was initiated in 2010. Depth-profiles in ½-meter increments were measured for water temperature, dissolved oxygen, pH, conductivity, ORP, turbidity, and chlorophyll *a*. Near-surface and near-bottom grab samples were collected from the thalweg of the river. The near-surface sample was collected by dipping a plastic churn bucket just below the water surface. The near-bottom sample was collected by lowering a finned-Van Dorn sampler to within ½-meter of the river bottom while the boat was drifting in the current.

6.2.2.1 Depth-Profile Plots

Depth-profile plots were constructed for water temperature, dissolved oxygen, pH, conductivity, turbidity, and chlorophyll *a* (Figure 6-1). The depth-profile plots indicate minimal variation in the six parameters with depth. The plots do indicate appreciable differences for selected parameters between monitoring dates.

Table 6-3. Summary of near-surface water quality conditions monitored in the Missouri River near Running Water, South Dakota (i.e., site GPTNFMORR1) at RM841 during 2009 and 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Streamflow (cfs)	1	16	31,499	28,948	15,562	50,456	-----	-----	-----
Water Temperature (°C)	0.1	15	13.6	13.9	1.1	27.2	27[1,2,6], 29[1,2,6]	0, 1	0%, 7%
Dissolved Oxygen (mg/l)	0.1	15	9.9	10.0	6.9	13.4	5[1,7]	0	0%
Dissolved Oxygen (% Sat.)	0.1	15	95.5	95.8	85.5	106.0	-----	-----	-----
pH (S.U.)	0.1	15	8.2	8.2	7.5	8.5	6.5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Specific Conductance (umhos/cm)	1	15	644	653	420	770	2,000[4]	0	0%
Oxidation-Reduction Potential	1	14	344	356	206	420	-----	-----	-----
Alkalinity, Total (mg/l)	7	16	145	146	132	156	-----	0	0%
Carbon, Total Organic (mg/l)	0.05	16	4.1	3.8	2.0	9.5	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	16	13	12	6	27	-----	-----	-----
Chloride (mg/l)	1	10	10	10	8	13	438[3,6], 250[3,8]	0	0%
Chlorophyll *a* (ug/l)	1	14	11	6	n.d.	42	-----	-----	-----
Color (S.U. - APHA)	1	15	10	9	5	31	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	16	437	428	314	622	1,750[3,6], 1,000[3,8], 3,500[5,6], 2,000[5,8]	0	0%
Hardness, Total (mg/l)	1	5	205	190	182	238	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	16	-----	0.03	n.d.	0.28	5.7 [1,6,9], 1.1 [1,8,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	16	0.7	0.5	0.2	1.3	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	16	0.38	0.30	n.d.	1.00	10[3,6], 100[4,6]	0	0%
Nitrogen, Total (mg/l)	0.1	16	1.0	0.8	0.5	2.3	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	12	0.03	0.03	n.d.	0.07	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	16	0.10	0.08	n.d.	0.33	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	16	-----	0.03	n.d.	0.09	-----	-----	-----
Suspended Solids, Total (mg/l)	4	16	53	33	4	180	158[1,6], 90[1,8]	1, 2	6%, 13%
THM Formation Potential, Total	4	13	218	200	74	464	-----	-----	-----
Turbidity (NTU)	1	15	42	25	n.d.	213	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	5	-----	n.d.	n.d.	n.d.	750[10], 87[11], 200[12]	0	0%
Antimony, Dissolved (ug/l)	0.5	5	-----	n.d.	n.d.	n.d.	88[10], 30[11], 6[12]	0	0%
Arsenic, Dissolved (ug/l)	1	5	2	2	2	3	340[10], 16.7[11], 10[12]	0	0%
Barium, Dissolved (ug/l)	5	5	54	54	37	75	2,000[11]	0	0%
Beryllium, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	n.d.	130[10], 5.3[11], 4[12]	0	0%
Cadmium, Dissolved (ug/l)	0.2	5	-----	n.d.	n.d.	n.d.	3.8[10], 0.38[11], 5[12]	0	0%
Chromium, Dissolved (ug/l)	10	5	-----	n.d.	n.d.	n.d.	964[10], 125[11], 100[12]	0	0%
Copper, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	n.d.	25[10], 16[11], 1,000[12]	0	0%
Iron, Dissolved (ug/l)	7	5	9	10	8	10	1,000[11]	0	0%
Lead, Dissolved (ug/l)	0.5	5	-----	n.d.	n.d.	n.d.	129[10], 5.0[11], 15[12]	0	0%
Manganese, Dissolved (ug/l)	2	5	20	18	n.d.	40	-----	-----	-----
Mercury, Dissolved (ug/l)	0.05	5	-----	n.d.	n.d.	n.d.	1.4[10]	0	0%
Mercury, Total (ug/l)	0.05	5	-----	n.d.	n.d.	n.d.	0.77[11], 2[12]	0	0%
Nickel, Dissolved (ug/l)	10	5	-----	n.d.	n.d.	n.d.	806[10], 90[11], 100[12]	0	0%
Selenium, Total (ug/l)	1	5	3	3	2	4	20[4,10], 5[11], 50[12]	0	0%
Silver, Dissolved (ug/l)	1	5	-----	n.d.	n.d.	n.d.	9.7[10], 100[12]	0	0%
Thallium, Dissolved (ug/l)	0.5	5	-----	n.d.	n.d.	n.d.	1,400[10], 6.3[11], 2[12]	0	0%
Zinc, Dissolved (ug/l)	5	5	-----	n.d.	n.d.	n.d.	202[10,11], 5,000[12]	0	0%
Pesticide Scan (ug/l)[D]	0.05[E]	2	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) 30-day average criterion (monitoring results not directly comparable to criterion).
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (10) Acute (CMC) criterion for the protection of freshwater aquatic life.
- (11) Chronic (CCC) criterion for the protection of freshwater aquatic life.
- (12) Criterion for the protection of human health.

Note: Some of South Dakota's and Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) Immunoassay analysis.

(E) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

(F) Detection limits vary by pesticide – 0.05 ug/l is a median detection limit for the pesticides in the pesticide scan.

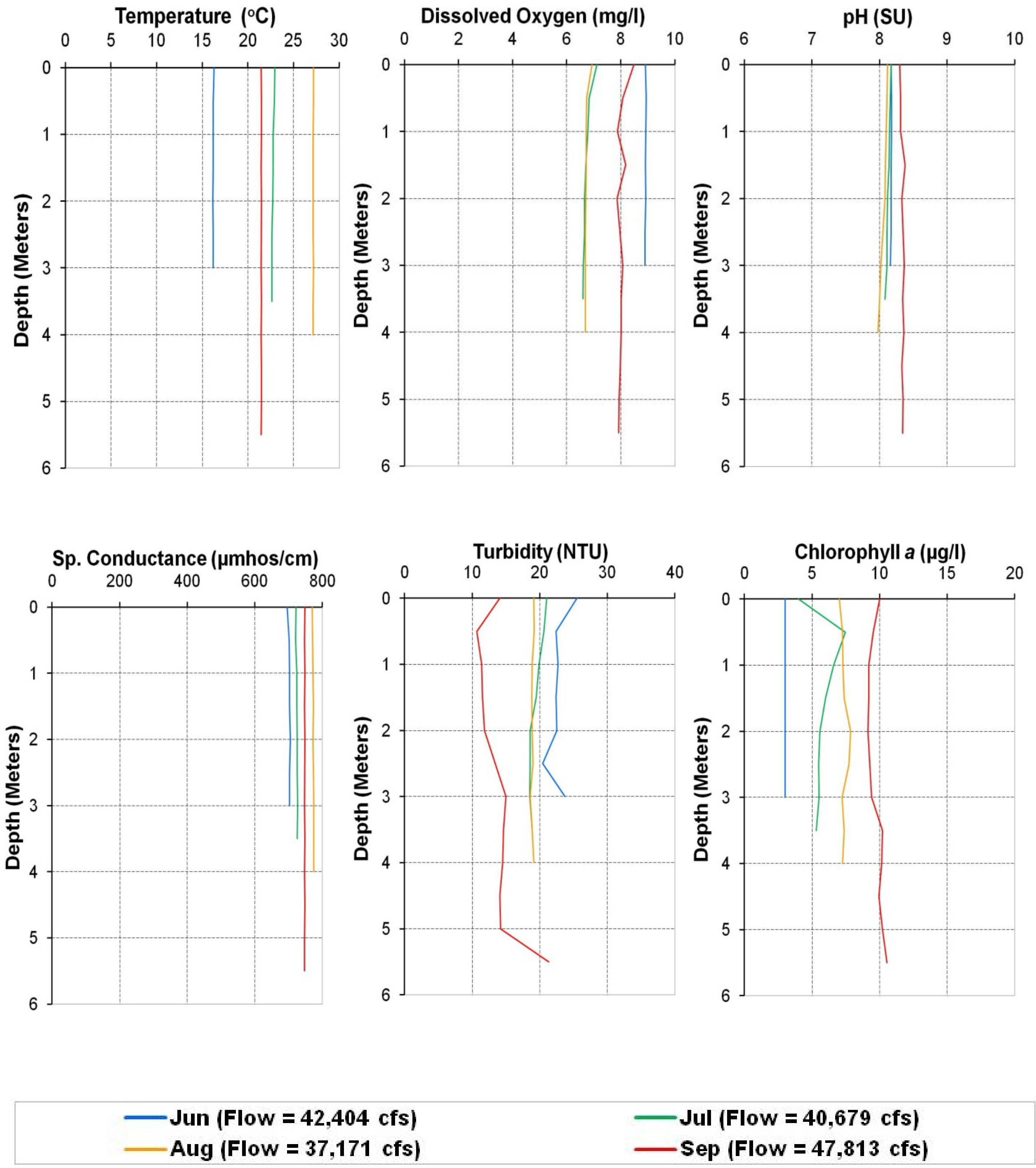

Figure 6-1. Water temperature, dissolved oxygen, pH, specific conductance, turbidity, and chlorophyll *a* depth profile plots for the Missouri River compiled from data collected at the site GPTNFMORR1 during 2010.

6.2.2.2 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Paired near-surface and near-bottom water quality samples collected at site GPTNFMORR1 during 2010 were compared. Four paired samples (June, July, August, and September) were collected during 2010. Box plots were constructed to display the distribution of the paired near-surface and near-bottom samples for selected non-particulate-associated (i.e., water temperature, total dissolved solid, dissolved sulfate, and dissolved phosphorus) and particulate-associated (i.e., total suspended solids, total suspended sediment, total Kjeldahl nitrogen, total phosphorus, and total organic carbon) constituents (Figure 6-2). Anecdotally, the box plots indicate little observable depth variation in the non-particulate- associated constituents. The box plots of the particulate-associated constituents indicate the maximum values for all these constituents, except TKN, were associated with the bottom samples. A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were not found to be significantly different for any parameter. It is noted that the small sample size limited the power of the applied statistical method to test for significant differences, and more testing will be done in the future as additional samples are collected.

The near-surface and near-bottom concentrations of the particulate-associated constituents total phosphorus, total Kjeldahl nitrogen, total suspended sediment, total suspended solids, and total organic carbon measured at site GTPNFMORR1 were plotted against the flow of the Missouri River at the time of sampling (Figure 6-3). Near-bottom concentrations of the particulate-associated constituents were higher than the near-surface levels during most instances. In one case, the measured near-surface concentration of TKN was higher than the paired near-bottom measured concentration.

6.2.3 NUTRIENT FLUX CONDITIONS

Nutrient flux rates of the Missouri River were calculated based on near-surface water quality samples collected at site GPTNFMORR1 near Running Water, SD and the instantaneous flow conditions at the time of sample collection (Table 6-4). It must be recognized that the concentrations of particulate-associated constituents can vary significantly from the river surface to its bottom because of the sinking of particulate matter and its transport nearer the river bottom. Since the instantaneous concentration of particulate-associated constituents (i.e., total phosphorus and total organic carbon) are likely higher nearer the river bottom, near-surface grab samples likely under estimate the “true” water-column composite concentration for these constituents. Thus, the flux rates given for total phosphorus and total organic carbon in Table 6-4 should be considered minimum estimates with the actual flux rates being higher. Figure 6-1, Figure 6-2, and Figure 6-3 compare near-surface and near-bottom water quality conditions monitored at site GPTNFMORR1. The maximum nutrient flux rates are attributed to greater nonpoint-source nutrient loadings associated with runoff conditions.

Table 6-4. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River near Running Water, South Dakota (i.e., site GPTNFMORR1) for 2009 and 2010.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	16	16	16	16	16	12	16
Mean	31,499	0.0297	0.5691	0.3147	0.0742	0.0385	3.5053
Median	28,948	0.0253	0.5166	0.2613	0.0725	0.0309	3.0197
Minimum	15,562	n.d.	0.1309	n.d.	n.d.	n.d.	1.6913
Maximum	50,456	0.1257	1.4104	1.1852	0.1541	0.1083	6.4505

Note: Non-detect values set to 0 for flux calculations.

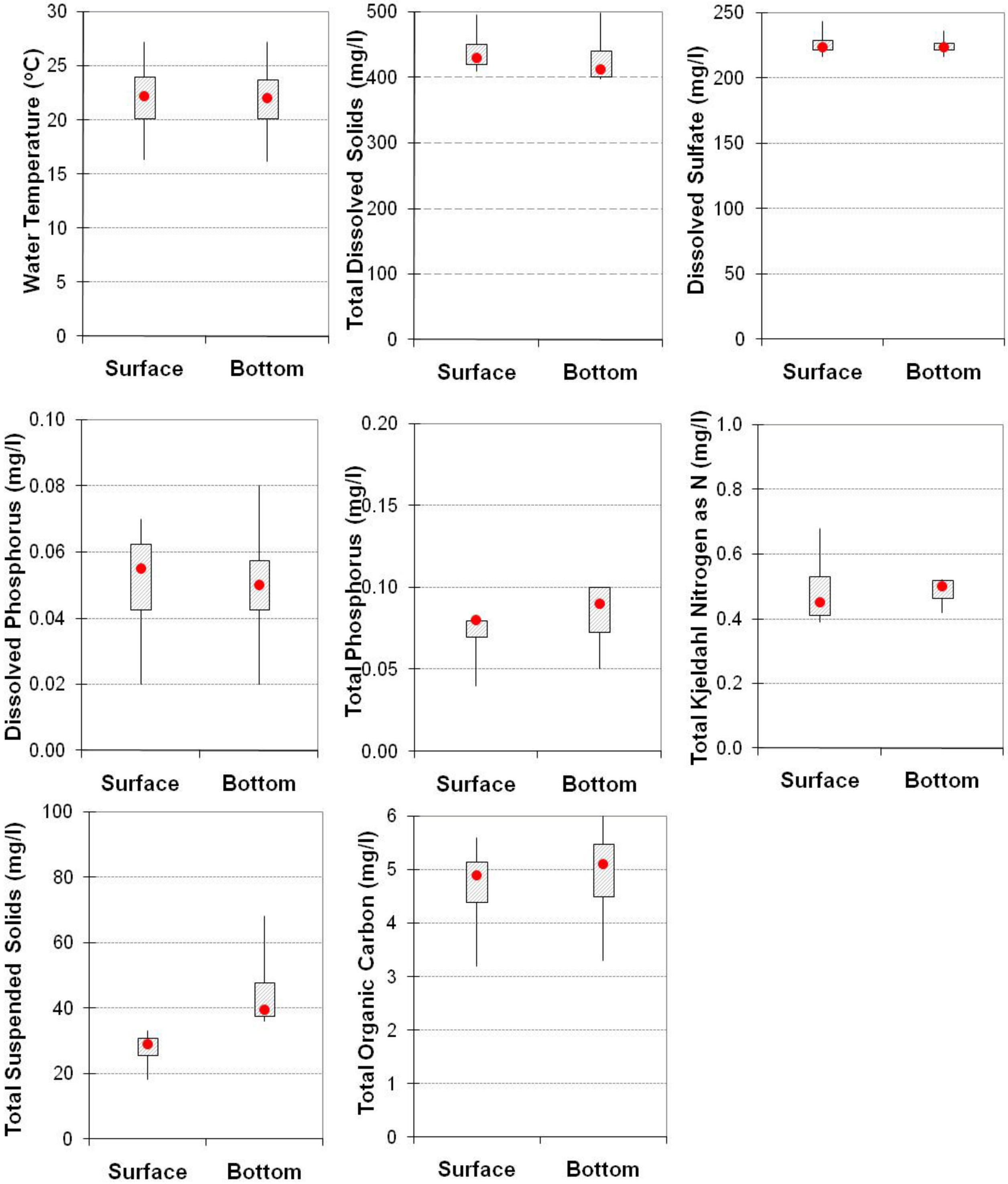

Figure 6-2. Box plots comparing paired surface and bottom water temperature, total dissolved solids, dissolved sulfate, dissolved phosphorus, total phosphorus, total Kjeldahl nitrogen, total suspended solids, and total organic carbon measurements taken in the Missouri River at site GPTNFMORR1 during 2010. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

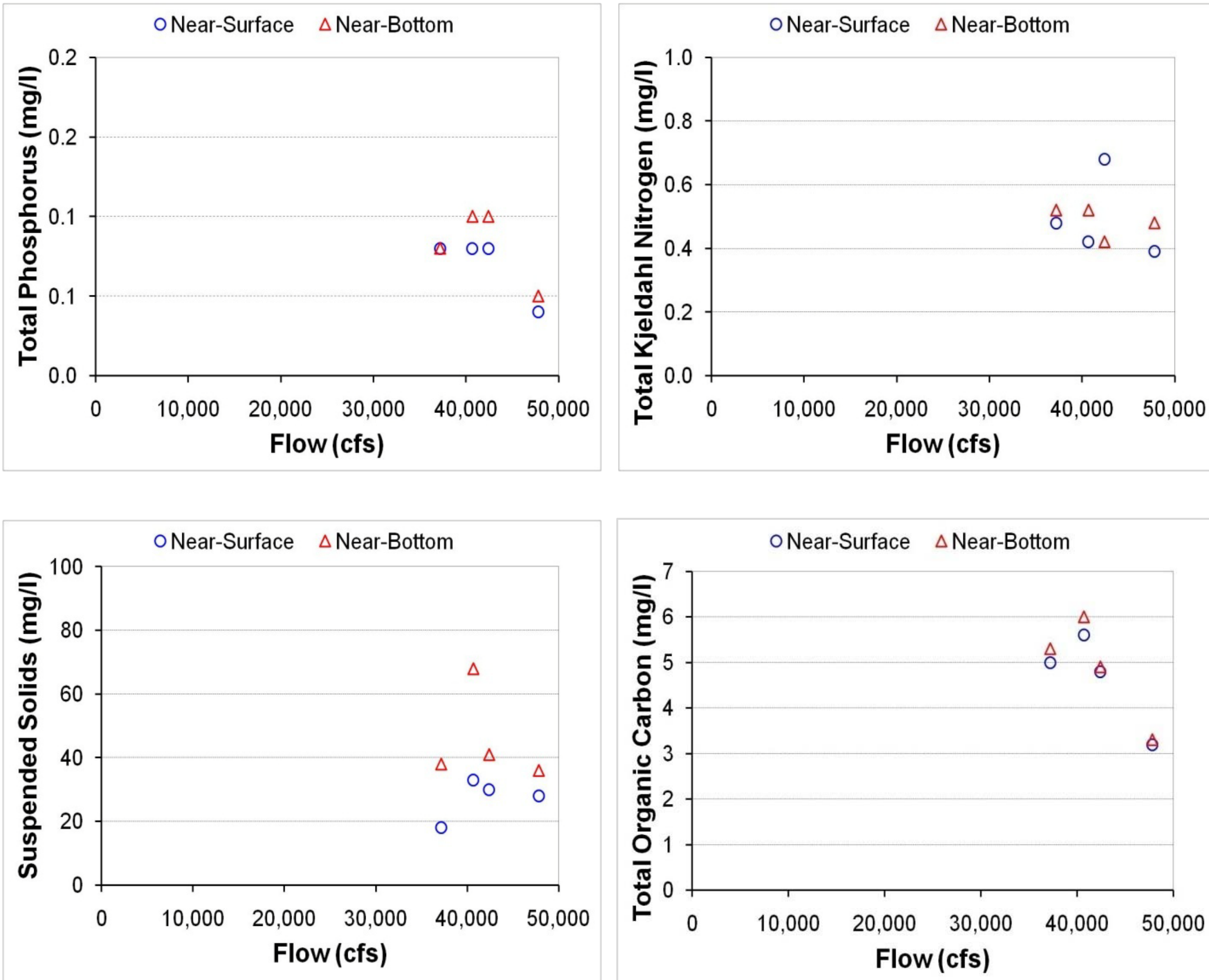

Figure 6-3. Comparison of flow and measured near-surface and near-bottom concentrations of total phosphorus, total Kjeldahl nitrogen, total suspended solids, and total organic carbon in the Missouri River near Running Water, SD (i.e., site GPTNFMORR1).

6.2.4 MEAN DAILY DISCHARGE AND TEMPERATURE

The estimated mean daily discharge and temperature of the annual Missouri River inflow to Lewis and Clark Lake for the 3-year period 2008 through 2010 are plotted in Figure 6-4, Figure 6-5, and Figure 6-6. The mean daily discharge was estimated by adding the mean daily discharges determined for the Fort Randall Dam outflow and Niobrara River near Verdel, NE at USGS gaging station 06465500. The mean daily temperature was estimated by flow weighting the mean daily water temperatures determined at the two sites.

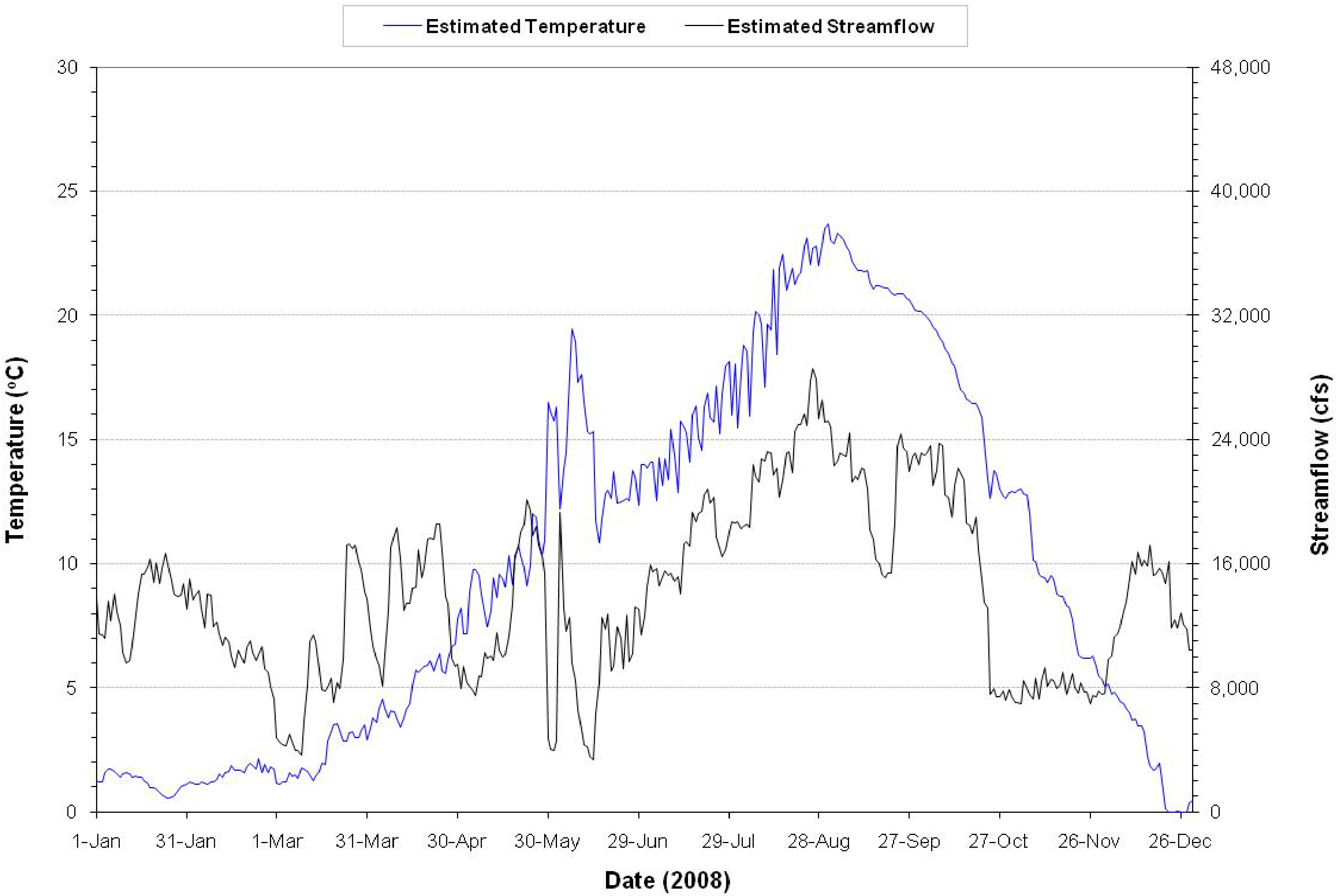

Figure 6-4. Mean daily water temperature and streamflow estimated for the Missouri River inflow to Lewis and Clark Lake for 2008. The mean daily discharge was estimated by adding the mean daily discharges determined for the Fort Randall Dam outflow and Niobrara River near Verdel, Nebraska at USGS gaging station 06465500. The mean daily temperature was estimated by flow weighting the mean daily water temperatures determined at the two sites.

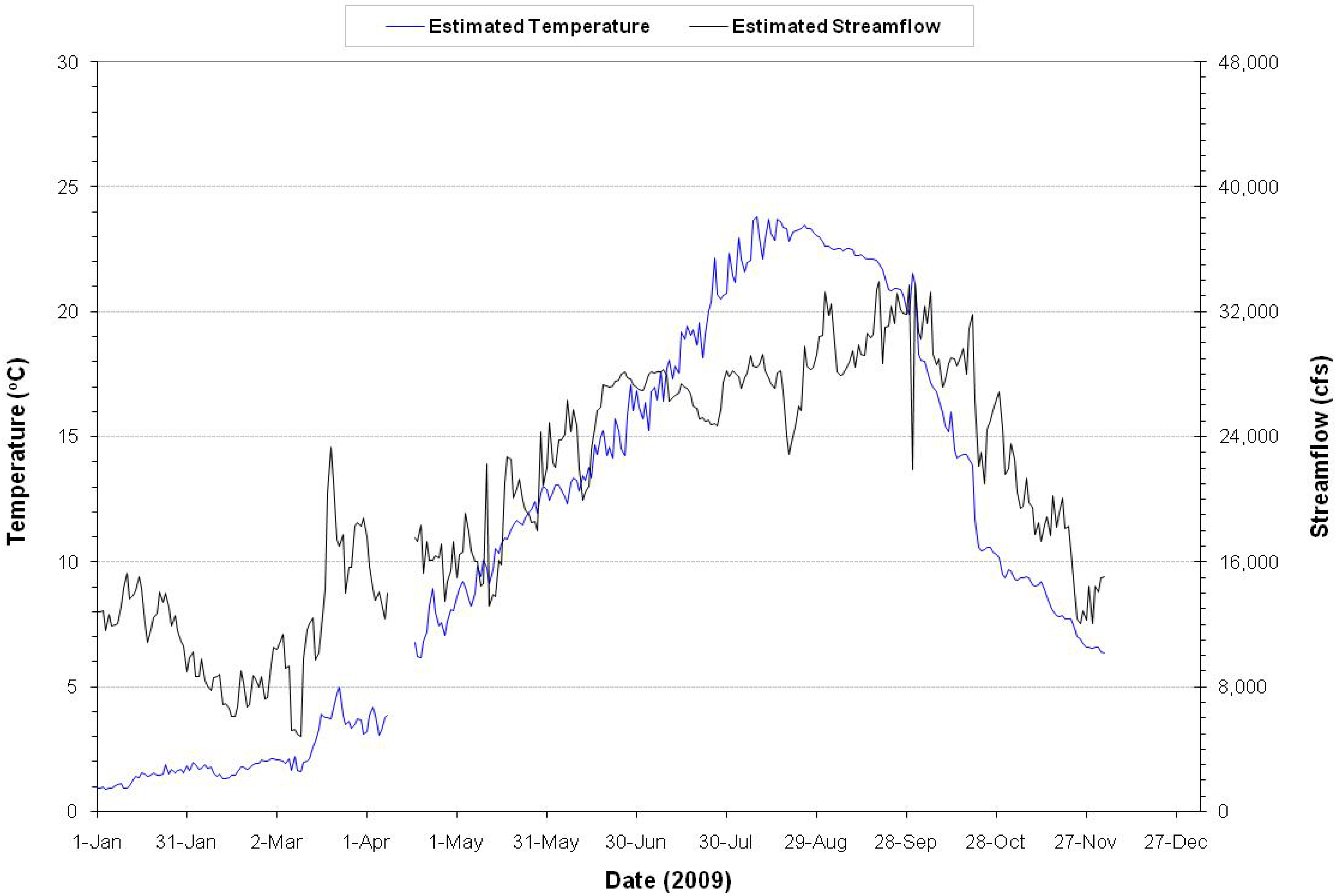

Figure 6-5. Mean daily water temperature and streamflow estimated for the Missouri River inflow to Lewis and Clark Lake for 2009. The mean daily discharge was estimated by adding the mean daily discharges determined for the Fort Randall Dam outflow and Niobrara River near Verdel, Nebraska at USGS gaging station 06465500. The mean daily temperature was estimated by flow weighting the mean daily water temperatures determined at the two sites.

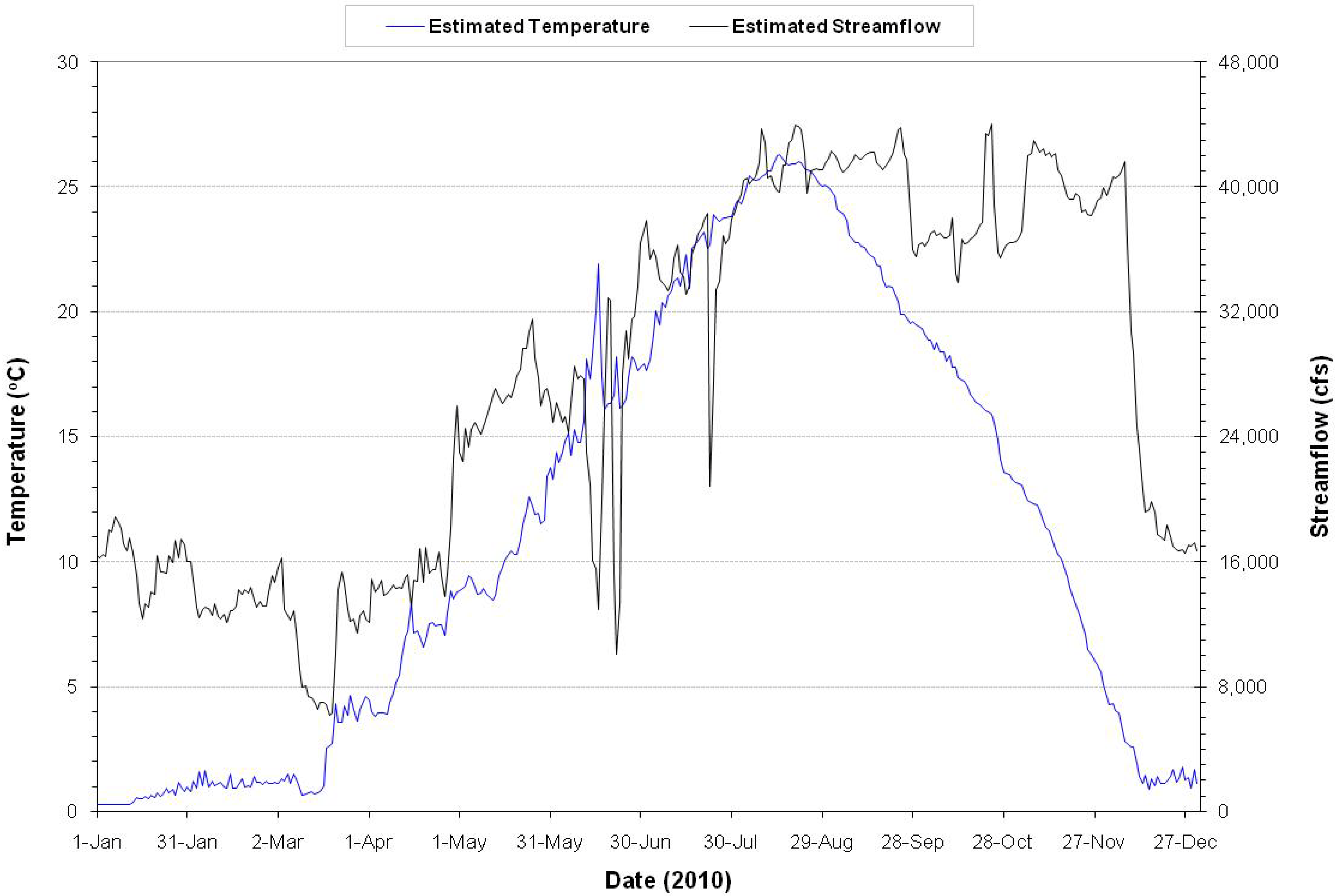

Figure 6-6. Mean daily water temperature and streamflow estimated for the Missouri River inflow to Lewis and Clark Lake for 2010. The mean daily discharge was estimated by adding the mean daily discharges determined for the Fort Randall Dam outflow and Niobrara River near Verdel, Nebraska at USGS gaging station 06465500. The mean daily temperature was estimated by flow weighting the mean daily water temperatures determined at the two sites.

7 WATER QUALITY CONDITIONS OF THE MISSOURI RIVER DOWNSTREAM OF GAVINS POINT DAM

7.1 WATER QUALITY CONDITIONS OF WATER DISCHARGED THROUGH GAVINS POINT DAM

7.1.1 STATISTICAL SUMMARY AND WATER QUALITY STANDARDS ATTAINMENT

Table 7-1 and Table 7-2 summarize the water quality conditions that were monitored monthly on water discharged through the Gavins Point powerplant during the 3-year period 2008 through 2010. These results indicate no major water quality standards concerns.

7.1.2 NUTRIENT FLUX CONDITIONS OF THE GAVINS POINT DAM DISCHARGE TO THE MISSOURI RIVER

Nutrient flux rates for the Gavins Point Dam discharge to the Missouri River over the 3-year period 2008 through 2010 were calculated based on samples taken from the Gavins Point powerplant (i.e. site GPTPP1) and the dam discharge at the time of sample collection (Table 7-3). The samples collected in the powerplant are taken from the raw water supply line and are believed to be unbiased regarding particulate-associated constituents. Therefore, the flux rates calculated for the Gavins Point Dam discharge give an unbiased estimate of the flux rates for all the constituents, including total phosphorus and total organic carbon. The maximum flux rates for all the constituents are believed to be attributed to higher dam discharges.

7.1.3 GAVINS POINT DAM TEMPERATURE, DISSOLVED OXYGEN, AND DISCHARGE TIME-SERIES PLOTS

Semiannual time-series for temperature, dissolved oxygen, and dam discharge monitored at the Gavins Point powerplant during the 3-year period 2008 through 2010 were plotted. Water temperatures showed seasonal warming and cooling through each calendar year (Plate 40 - Plate 45). Dissolved oxygen levels remained relatively high and fairly stable during the winter, steadily declined through the spring and summer, and steadily increased during the fall (Plate 46 - Plate 51). The lowest dissolved oxygen levels occurred during the July to August period. The higher winter, declining spring, and increasing fall dissolved oxygen concentrations are attributed to decreasing dissolved oxygen solubility with warmer water temperatures. There didn’t appear to be significant correlation between discharge rates and measured water temperature and dissolved oxygen concentrations.

7.1.4 COMPARISON OF MONITORED INFLOW AND OUTFLOW TEMPERATURES OF THE MISSOURI RIVER AT LEWIS AND CLARK LAKE

Figure 7-1, Figure 7-2, and Figure 7-3, respectively, plot the mean daily water temperatures estimated for the Missouri River inflow to Lewis and Clark Lake and for the discharge from Gavins Point Dam (site GPTPP1) for 2008, 2009, and 2010. Inflow temperatures of the Missouri River to Lewis and Clark Lake are about 4° to 8°C cooler than the outflow temperatures of Gavins Point Dam during the spring and summer. Outflow temperatures of the Gavins Point Dam discharge are about 2° to 4°C cooler than the inflow temperatures of the Missouri River during the fall.

Table 7-1. Summary of annual metals and pesticide levels monitored on water discharged through Gavins Point Dam (i.e., site GPTPP1) during the 3-year period of 2008 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
Aluminum, Dissolved (ug/l)	25	3	-----	n.d.	n.d.	n.d.	750(1), 87(2), 200(3)	0	0%
Aluminum, Total (ug/l)	25	3	352	300	200	556	-----	-----	-----
Antimony, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	0.8	88(1), 30(2), 6(3)	0	0%
Antimony, Total (ug/l)	0.5	3	-----	n.d.	n.d.	1.0	5.6(4)	0	0%
Arsenic, Dissolved (ug/l)	1	3	2	2	2	3	340(1), 16.7(2)	0	0%
Arsenic, Total (ug/l)	1	3	2	2	2	3	10(3), 0.018(4)	0, 3	0%, 100%
Barium, Dissolved (ug/l)	5	3	50	49	46	54	-----	-----	-----
Barium, Total (ug/l)	5	3	51	50	50	54	2,000(3)	0	0%
Beryllium, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	130(1), 5.3(2)	0	0%
Beryllium, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	4(4)	0	0%
Cadmium, Dissolved (ug/l)	0.2	3	-----	n.d.	n.d.	n.d.	4.3(1), 0.43(2)	0	0%
Cadmium, Total (ug/l)	0.2	3	-----	n.d.	n.d.	n.d.	5(3,4)	0	0%
Calcium, Dissolved (mg/l)	0.01	3	58	59	54	62			
Chromium, Dissolved (ug/l)	10	3	-----	n.d.	n.d.	n.d.	1,087(1), 141(2)	0	0%
Chromium, Total (ug/l)	10	3	-----	n.d.	n.d.	n.d.	100(3)	-----	-----
Copper, Dissolved (ug/l)	2	3	-----	10	n.d.	10	28(1), 18(2),	0	0%
Copper, Total (ug/l)	2	3	-----	10	n.d.	140	1,300(3,4)	0	0%
Hardness, Total (mg/l)	1	3	222	220	208	238	-----	-----	-----
Iron, Dissolved (ug/l)	40	3	-----	n.d.	n.d.	n.d.	1,000(2)	0	0%
Iron, Total (ug/l)	40	3	300	240	190	470	-----	-----	-----
Lead, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	151(1), 5.9(2)	0	0%
Lead, Total (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Magnesium, Dissolved (mg/l)	0.01	3	19	19	18	20			
Manganese, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	7	1,000(2)	0	0%
Manganese, Total (ug/l)	2	3	56	50	48	70	-----	-----	-----
Mercury, Dissolved (ug/l)	0.05	3	-----	n.d.	n.d.	n.d.	1.4(1)	0	0%
Mercury, Total (ug/l)	0.05	3	-----	n.d.	n.d.	n.d.	0.77(2), 0.05(3), 2(3)	0	0%
Nickel, Dissolved (ug/l)	10	3	-----	n.d.	n.d.	n.d.	912(1), 101(2)	0	0%
Nickel, Total (ug/l)	10	3	-----	n.d.	n.d.	n.d.	610(4)	0	0%
Selenium, Total (ug/l)	1	3	3	3	2	5	20(1), 5(2), 50(3), 170(4)	0	0%
Silver, Dissolved (ug/l)	1	3	-----	n.d.	n.d.	n.d.	13(1)	0	0%
Silver, Total (ug/l)	1	3	-----	n.d.	n.d.	n.d.	10(3)	0	0%
Thallium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	1,400(1), 6.3(2), 2(3), 0.24(3)	0	0%
Thallium, Total (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	0.24(3)	b.d.	b.d.
Zinc, Dissolved (ug/l)	10	3	-----	n.d.	n.d.	n.d.	229(1,2)	0	0%
Zinc, Total (ug/l)	10	3	-----	n.d.	n.d.	n.d.	5,000(4), 7,400(4)	0	0%
Pesticide Scan (ug/l)(D)	0.05(E)	3	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected, b.d. = Criterion below detection limit.

(A) Results for iron (dissolved and total) and manganese (dissolved and total) include some monthly samples.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Acute (CMC) criterion for the protection of freshwater aquatic life.

(2) Chronic (CCC) criterion for the protection of freshwater aquatic life.

(3) Criterion for the protection of domestic water supply waters.

(4) Criterion for the protection of human health.

Note: Some of South Dakota's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

(E) Detection limits vary by pesticide – 0.05 ug/l is a median detection limit for the pesticides in the pesticide scan.

Table 7-2. Summary of water quality conditions monitored on water discharged through Gavins Point Dam (i.e., site GPTPP1) during the 3-year period of 2008 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
Dam Discharge (cfs)	1	29	20,111	17,986	8,974	34,110	-----	-----	-----
Water Temperature (°C)	0.1	29	13.4	13.2	0.3	26.1	27(1,2,6), 29(1,2,6)	0	0%
Dissolved Oxygen (mg/l)	0.1	29	10.1	10.1	2.6	13.9	5(1,7)	1	3%
Dissolved Oxygen (% Sat.)	0.1	29	97.7	99.4	20.1	121.6	-----	-----	-----
pH (S.U.)	0.1	29	8.3	8.3	7.1	8.9	6.5(1,3,7), 9.0(1,3,6), 9.5(5,6)	0	0%
Specific Conductance (umhos/cm)	1	28	696	706	489	762	2,000(4)	-----	-----
Oxidation-Reduction Potential (mV)	1	28	344	358	148	464	-----	-----	-----
Turbidity (NTU)	1	28	13	10	n.d.	97	-----	-----	-----
Alkalinity, Total (mg/l)	7	29	153	155	129	165	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	29	4.1	3.8	1.9	13.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	29	13	12	n.d.	35	-----	-----	-----
Chloride, Dissolved (mg/l)	1	20	12	12	10	19	438(3,6), 250(3,8)	0	0%
Color (APHA)	1	9	9	8	6	12	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	29	447	452	324	522	1,750(2,4), 1,000(2,7), 3,500(3,4), 2,000(3,6)	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	29	-----	0.02	n.d.	0.44	4.7(1,6,9), 1.4(1,8,9)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	29	0.6	0.6	n.d.	1.8	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	29	-----	0.15	n.d.	0.60	10(3,6), 100(4,6)	0	0%
Nitrogen, Total (mg/l)	0.1	29	0.8	0.8	0.1	2.3	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	29	-----	0.02	n.d.	0.30	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	29	0.06	0.04	0.02	0.38	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	29	-----	0.02	n.d.	0.19	-----	-----	-----
Sulfate (mg/l)	1	29	193	195	107	233	875(3,6), 500(3,8)	0	0%
Suspended Solids, Total (mg/l)	4	29	-----	7	n.d.	71	158(1,6), 90(1,8)	0	0%

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
(2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
(3) Criteria for the protection of domestic water supply waters.
(4) Criteria for the protection of agricultural water supply waters.
(5) Criteria for the protection of commerce and industry waters.
(6) Daily maximum criterion (monitoring results directly comparable to criterion).
(7) Daily minimum criterion (monitoring results directly comparable to criterion).
(8) 30-day average criterion (monitoring results not directly comparable to criterion).
(9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

Table 7-3. Summary of nutrient flux rates (kg/sec) calculated for the Gavins Point Dam total discharge to the Missouri River (i.e., site GTPPP1) during January through December over the 3-year period 2008 through 2010.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	29	29	29	29	29	29	29
Mean	21,306	0.0199	0.3611	0.0845	0.0300	0.0174	2.4998
Median	17,986	0.0102	0.2801	0.0679	0.0221	0.0118	1.8833
Minimum	8,974	n.d.	n.d.	n.d.	0.0085	n.d.	0.7623
Maximum	49,065	0.1123	0.9497	0.2898	0.0970	0.0925	7.1371

Note: Nondetectable values set to 0 for flux calculations.

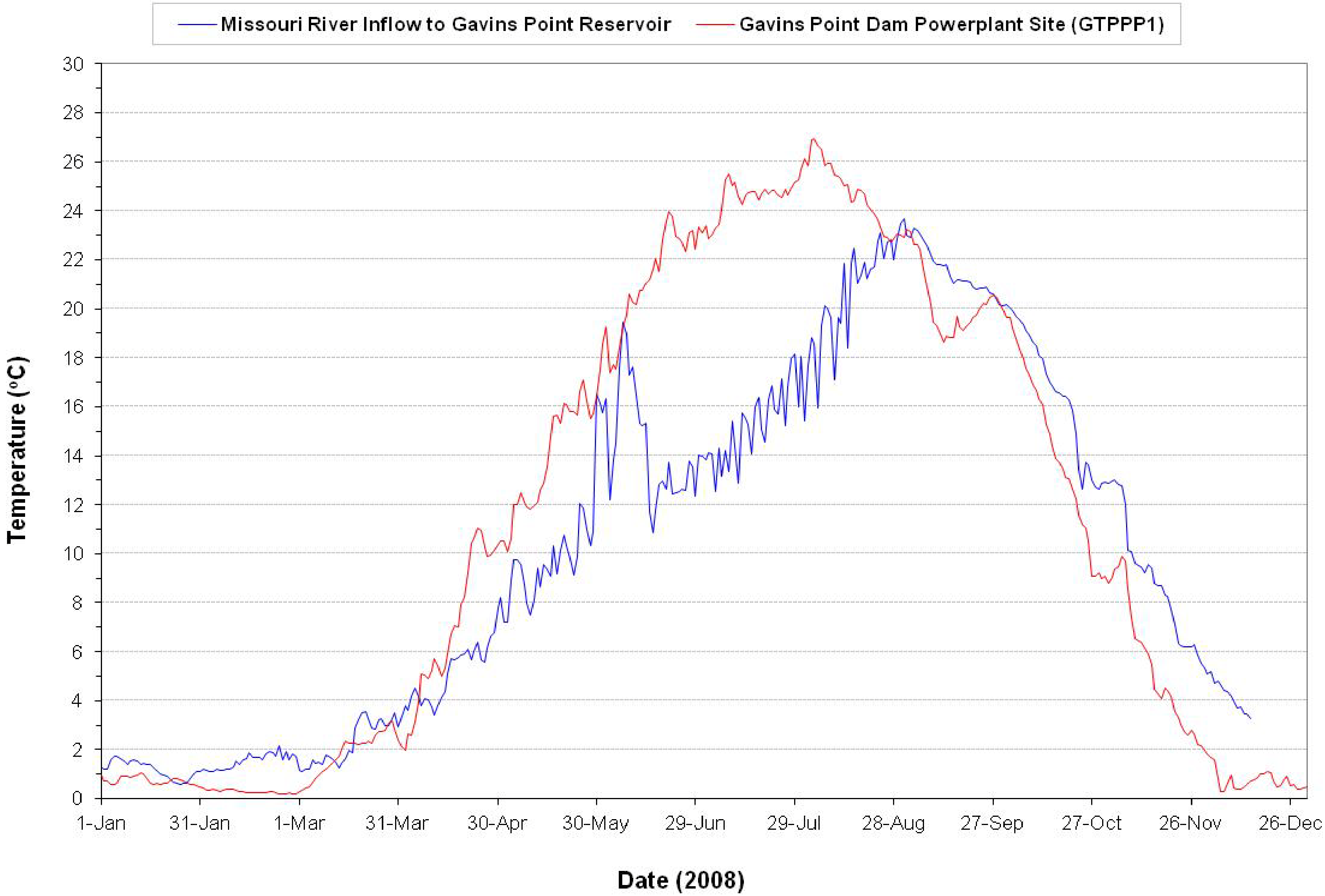

Figure 7-1. Mean daily water temperatures estimated for the Missouri River inflow to Lewis and Clark Lake and for the discharge from Gavins Point Dam (i.e., site GPTPP1) during 2008.

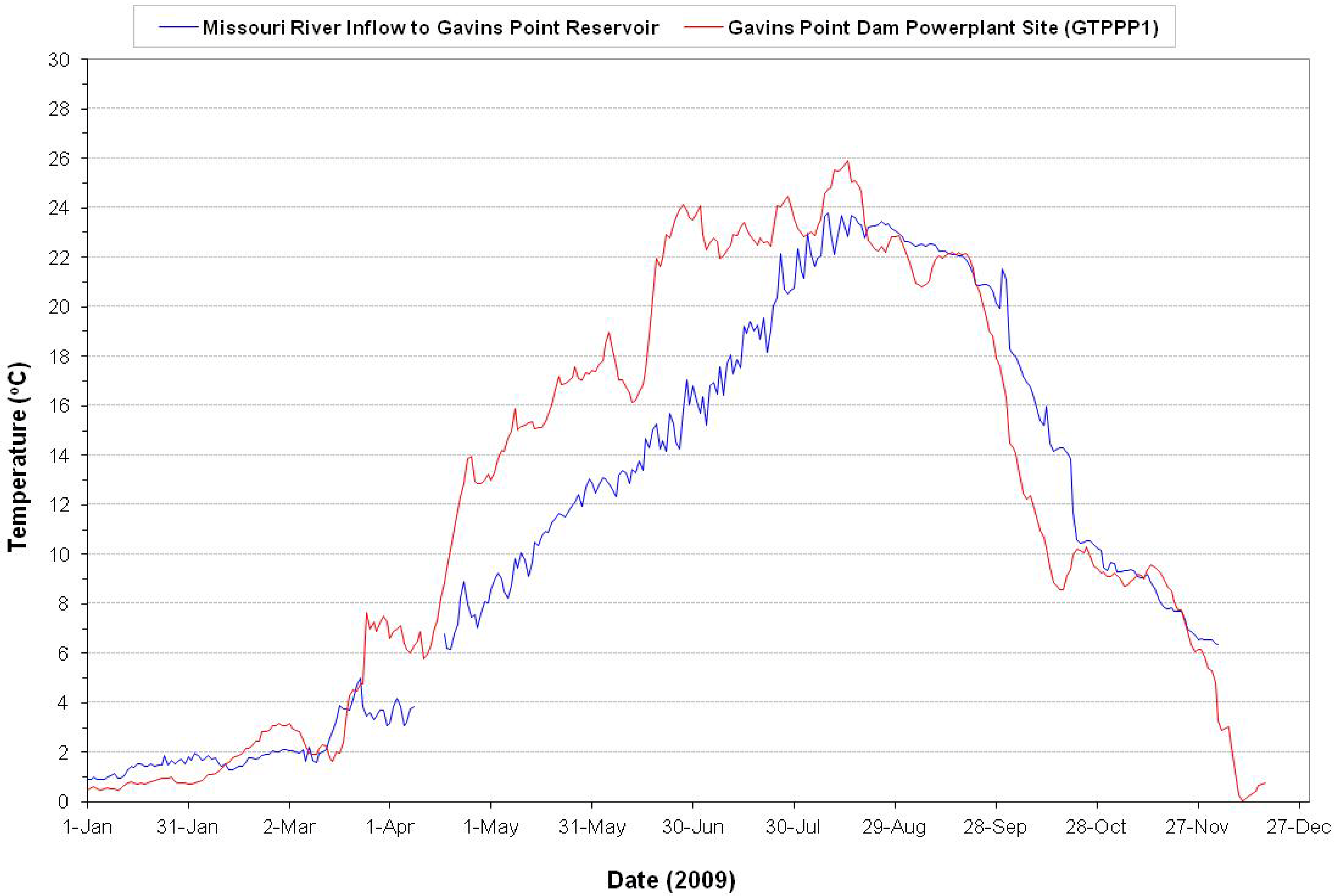

Figure 7-2. Mean daily water temperatures estimated for the Missouri River inflow to Lewis and Clark Lake and for the discharge from Gavins Point Dam (i.e., site GPTPP1) during 2009.

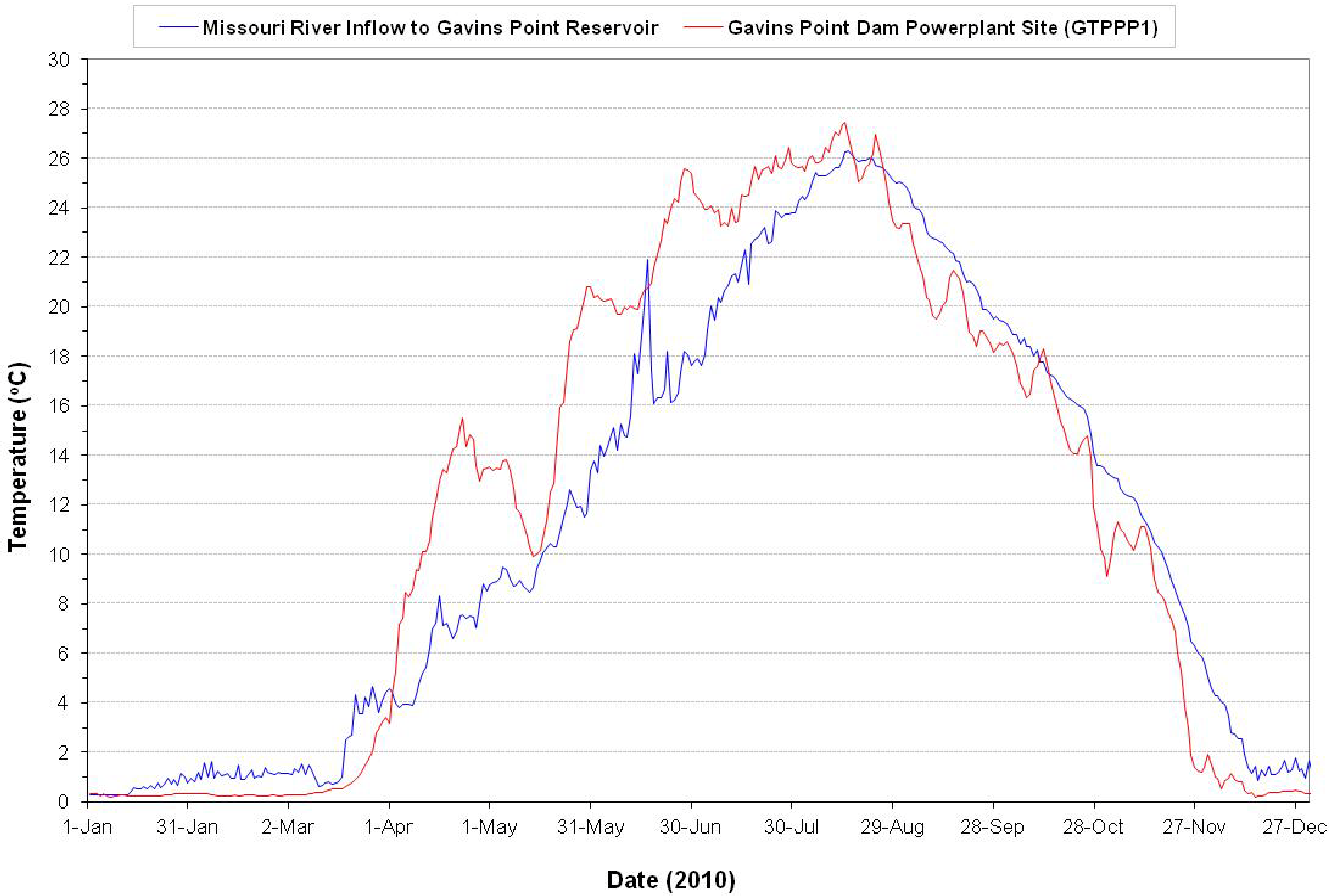

Figure 7-3. Mean daily water temperatures estimated for the Missouri River inflow to Lewis and Clark Lake and for the discharge from Gavins Point Dam (i.e., site GPTPP1) during 2010.

7.2 MISSOURI RIVER AT THE GAVINS POINT DAM TAILWATERS

7.2.1 STATISTICAL SUMMARY AND COMPARISON TO APPLICABLE WATER QUALITY STANDARDS CRITERIA

The water quality conditions that were monitored in the Missouri River in the Gavins Point Dam tailwaters at site GPTRRTW1 (Figure 3-1) during the 3-year period 2008 through 2010 are summarized in Table 7-4. A review of these results indicated no significant water quality concerns.

7.2.2 VERTICAL WATER QUALITY VARIATION IN THE MISSOURI RIVER

Depth discrete water quality monitoring of the Missouri River at site GPTRRTW1 was initiated in 2010. Depth-profiles for water temperature, dissolved oxygen, pH, conductivity, ORP, turbidity, and chlorophyll *a* were measured in ½-meter increments while drifting in a boat along the river thalweg. Near-surface, mid-depth, and near-bottom grab samples were also collected from the thalweg of the river. The near-surface sample was collected by dipping a plastic churn bucket just below the water surface. The mid-depth and near-bottom samples were collected by triggering a finned-Van Dorn sampler at the appropriate depth while the boat was drifting in the current.

7.2.2.1 Depth-Profile Plots

Depth-profile plots were constructed for water temperature, dissolved oxygen, pH, conductivity, turbidity, and chlorophyll *a* (Figure 7-4). The depth-profile plots indicate minimal variation in the six parameters with depth, with chlorophyll *a* showing the most variation. The plots do indicate appreciable differences for selected parameters between monitoring dates

7.2.2.1.1 Comparison of Near-Surface, Mid-Depth and Near-Bottom Water Quality Conditions

The near-surface, mid-depth, and near-bottom concentrations of the particulate-associated constituents total phosphorus, total Kjeldahl nitrogen, total suspended solids, total suspended sediment, and total organic carbon measured at site GPTRRTW1 were plotted against the flow of the Missouri River at the time of sampling (Figure 7-5). The measured concentrations of the particulate-associated constituents exhibited little observable correlation to depth, and seemingly only a slight increase with increasing flow. This may be attributed to the site location (i.e., dam tailwaters) and the impacts of the dam and upstream reservoir on the discharged water.

Paired near-surface, mid-depth, and near-bottom water quality samples collected at site GPTRRTW1 during 2010 were compared. Seven paired samples (April, May, June, July, August, September, and October) were collected during 2010. Box plots were constructed to display the distribution of the paired near-surface, mid-depth, and near-bottom measurements for selected non-particulate-associated (i.e., water temperature and specific conductance) and particulate-associated (i.e., total suspended solids, total suspended sediment, turbidity, total Kjeldahl nitrogen, total phosphorus, and total organic carbon) constituents (Figure 7-6). Anecdotally, the box plots indicate little observable depth variation in the non-particulate-associated constituents. The box plots of the particulate-associated constituents exhibited more variation. A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were not found to be significantly different for any parameter.

Table 7-4. Summary of near-surface water quality conditions monitored in the Missouri River at the Gavins Point Dam tailwaters (i.e., site GPTRRTW1) during the 3-year period 2008 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
Gavins Point Dam Discharge:									
Streamflow (cfs)	1	37	19,600	16,981	8,985	46,937	-----	-----	-----
Field Measurements:									
Water Temperature (°C)	0.1	36	11.3	10.0	0.0	26.8	27(1,2,6), 29(1,2,6)	0	0%
Dissolved Oxygen (mg/l)	0.1	35	10.8	11.6	7.0	15.1	5(1,7)	0	0%
Dissolved Oxygen (% Sat.)	0.1	35	97.6	97.2	88.1	115.3	-----	-----	-----
Oxidation-Reduction Potential	1	33	360	368	150	472	-----	-----	-----
pH (S.U.)	0.1	35	8.2	8.3	7.8	8.8	6.5(1,3,7), 9.0(1,3,6), 9.5(5,6)	0	0%
Specific Conductance (umhos/cm)	1	36	704	707	601	800	2,000(4)	0	0%
Turbidity (NTU)	1	35	18	8	n.d.	149	-----	-----	-----
Laboratory Results:									
Alkalinity, Total (mg/l)	7	36	156	156	138	170	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	36	3.8	3.8	2.4	5.8	-----	-----	-----
CBOD 5-day (mg/l)	2	6	2	3	n.d.	3	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	36	12	12	n.d.	21	-----	-----	-----
Chloride (mg/l)	1	35	12	12	10	17	438(3,6), 250(3,8)	0	0%
Chlorophyll *a* (ug/l)	1	17	13	12	2	29	-----	-----	-----
Color (APHA)	1	21	7	7	n.d.	14	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	36	453	440	382	550	1,750(3,6), 1,000(3,8), 3,500(5,6), 2,000(5,8)	0	0%
Nitrogen, Ammonia Total	0.02	36	-----	0.03	n.d.	0.25	4.7 (1,6,9), 1.5 (1,8,9)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	36	0.5	0.5	n.d.	1.2	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	36	-----	0.17	n.d.	0.40	10(3,6), 100(4,6)	0	0%
Nitrogen, Total (mg/l)	0.1	36	0.7	0.7	0.1	1.4	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	15	-----	n.d.	n.d.	0.07	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	36	0.04	0.04	n.d.	0.09	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	21	-----	n.d.	n.d.	0.04			
Sulfate (mg/l)	1	21	205	205	169	233	-----	-----	-----
Suspended Sediment, Total (mg/l)	4	7	20	16	7	59	-----	-----	-----
Suspended Solids, Total (mg/l)	4	-----	10	7	n.d.	57	158(1,6), 90(1,8)	0	0%
THM Formation Potential, Total (mg/l)	4	15	229	191	152	356	-----	-----	-----

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Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[(A)]	No. of Obs.	Mean[(B)]	Median	Min.	Max.	State WQS Criteria[(C)]	No. of WQS Exceedances	Percent WQS Exceedance
Laboratory Results (Metals and Pesticides):									
Aluminum, Dissolved (mg/l)	25	8	-----	n.d.	n.d.	n.d.	750[(10)], 87[(11)], 200[(12)]	0	0%
Antimony, Dissolved (ug/l)	0.5	8	-----	n.d.	n.d.	1	88[(10)], 30[(11)], 6[(12)]	0	0%
Arsenic, Dissolved (ug/l)	1	8	2	2	1	3	340[(10)], 16.7[(11)], 10[(12)]	0	0%
Barium, Dissolved (ug/l)	5	8	50	49	33	65	2,000[(11)]	0	0%
Beryllium, Dissolved (ug/l)	2	8	-----	n.d.	n.d.	n.d.	130[(10)], 5.3[(11)], 4[(12)]	0	0%
Cadmium, Dissolved (ug/l)	0.5	8	-----	n.d.	n.d.	n.d.	4.4[(10)], 0.43[(11)], 5[(12)]	0	0%
Calcium, Dissolved (mg/l)	0.01	8	58	58	52	62	-----	-----	-----
Chromium, Dissolved (ug/l)	10	8	-----	n.d.	n.d.	n.d.	1,103[(10)], 143[(11)], 100[(12)]	0	0%
Copper, Dissolved (ug/l)	2	8	-----	n.d.	n.d.	n.d.	29[(10)], 18[(11)], 1,000[(12)]	0	0%
Hardness, Total (mg/l)	0.4	8	223	223	208	240	-----	-----	-----
Lead, Dissolved (ug/l)	0.5	8	-----	n.d.	n.d.	n.d.	154[(10)], 6.0[(11)], 15[(12)]	0	0%
Magnesium, Dissolved (mg/l)	0.01	4	20	19	19	21	-----	-----	-----
Mercury, Dissolved (ug/l)	0.05	8	-----	n.d.	n.d.	n.d.	1.4[(10)]	0	0%
Mercury, Total (ug/l)	0.05	8	-----	n.d.	n.d.	n.d.	0.77[(11)], 2[(12)]	0	0%
Nickel, Dissolved (ug/l)	10	8	-----	n.d.	n.d.	n.d.	926[(10)], 103[(11)], 100[(12)]	0	0%
Selenium, Total (ug/l)	1	8	3	3	2	5	20[(4,10)], 5[(11)], 50[(12)]	0	0%
Silver, Dissolved (ug/l)	1	8	-----	n.d.	n.d.	n.d.	13[(10)], 100[(12)]	0	0%
Thallium, Dissolved (ug/l)	0.5	8	-----	n.d.	n.d.	n.d.	1,400[(10)], 6.3[(11)], 2[(12)]	0	0%
Zinc, Dissolved (ug/l)	10	8	-----	n.d.	n.d.	n.d.	232[(10,11)], 5,000[(12)]	0	0%
Acetochlor, Total (ug/l)[(D)]	0.05	31	-----	n.d.	n.d.	0.40	-----	-----	-----
Alachlor, Total (ug/l)[(D)]	0.05	3	-----	n.d.	n.d.	n.d.	760[(10)], 76[(11)], 2[(12)]	0	0%
Atrazine, Total (ug/l)[(D)]	0.05	34	-----	n.d.	n.d.	0.50	330[(10)], 12[(11)], 3[(3)]	0	0%
Metolachlor, Total (ug/l)[(D)]	0.05	34	-----	n.d.	n.d.	0.10	390[(10)], 100[(11)]	0	0%
Pesticide Scan (ug/l)[(E)]	0.05						-----	-----	-----

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) 30-day average criterion (monitoring results not directly comparable to criterion).
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (10) Acute (CMC) criterion for the protection of freshwater aquatic life.
- (11) Chronic (CCC) criterion for the protection of freshwater aquatic life.
- (12) Criterion for the protection of human health.

Note: Some of South Dakota's and Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) Immunoassay analysis.

(E) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan. Individual pesticides were not detected unless listed under pesticide scan.

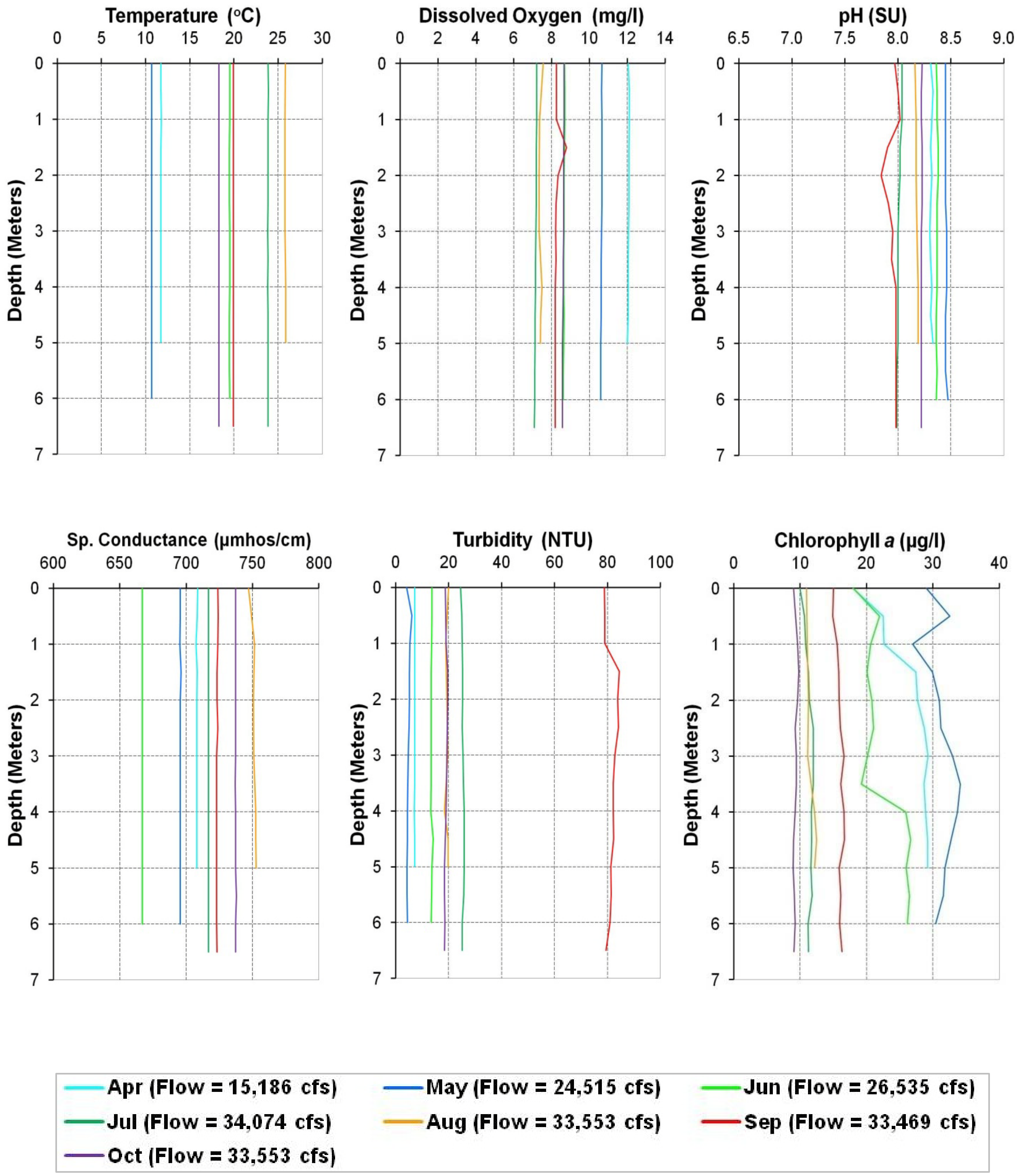

Figure 7-4. Water temperature, dissolved oxygen, pH, specific conductance, turbidity, and chlorophyll *a* depth profiles for the Missouri River compiled from data collected at the Gavins Point Dam tailwaters site (i.e., GPTPRRTW1) during 2010.

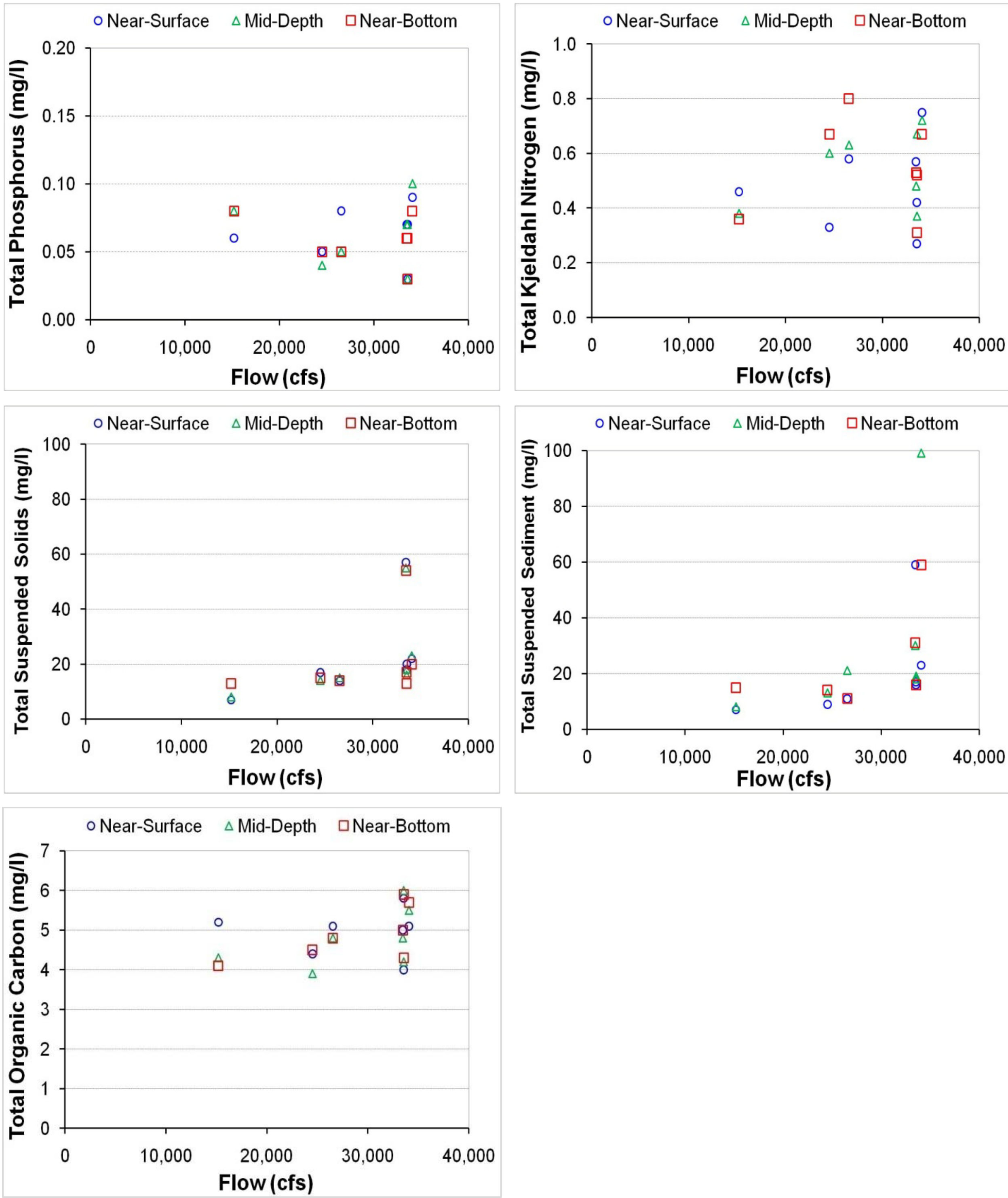

Figure 7-5. Comparison of flow and measured near-surface, mid-depth, and near-bottom concentrations of total phosphorus, total Kjeldahl nitrogen, total suspended solids, total suspended sediment, and total organic carbon in the Missouri River at the Gavins Point Dam tailwaters (i.e., site GPTRRTW1) during 2010.

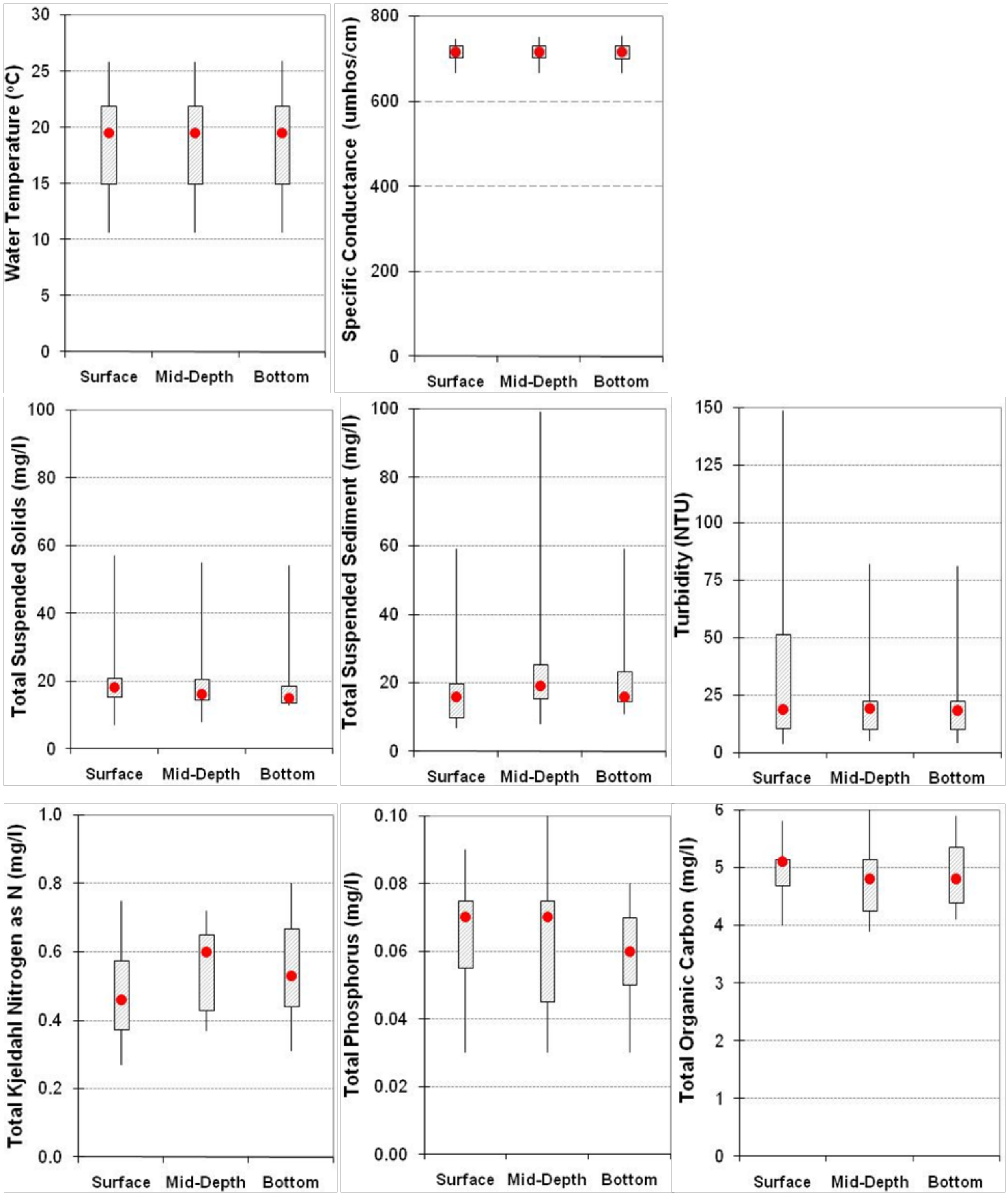

Figure 7-6. Box plots comparing paired surface, mid-depth, and bottom water temperature, specific conductance, total suspended solids, total suspended sediment, turbidity, total Kjeldahl nitrogen, total phosphorus, and total organic carbon measurements taken in the Missouri River at site GPTRRTW1 during 2010. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

7.2.3 NUTRIENT FLUX CONDITIONS

Nutrient flux rates for the Missouri River at the Gavins Point Dam tailwaters were calculated for the 3-year period 2008 through 2010. The calculated flux rates were based on near-surface water quality samples collected at site GPTRRTW1 and the instantaneous flow conditions at the time of sample collection (Table 7-5). It must be recognized that the concentrations of particulate-associated constituents can vary significantly from the river surface to its bottom because of the sinking of particulate matter and its transport nearer the river bottom. Since the instantaneous concentration of particulate-associated constituents (i.e., total phosphorus and total organic carbon) could seemingly be higher nearer the river bottom, near-surface grab samples likely under estimate the "true" water-column composite concentration for these constituents. Thus, the given flux rates for total phosphorus and total organic carbon should be considered minimum estimates with the actual flux rates being potentially higher.

Table 7-5. Summary of near-surface nutrient flux rates (kg/sec) calculated for the Missouri River at the Gavins Point tailwaters (i.e., site GTPRRTW1) over the 3-year period 2008 through 2010.

Statistic	Missouri River Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	36	36	36	36	36	36
Mean	19,894	0.0223	0.2941	0.0876	0.0241	2.2034
Median	16,999	0.0180	0.2503	0.0625	0.0208	1.6002
Minimum	8,985	n.d.	n.d.	n.d.	n.d.	0.8663
Maximum	46,937	0.1061	0.7236	0.3859	0.0868	6.1137

n.d. = Nondetectable.
Note: Non-detect values set to 0 for flux calculations.

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 EXISTING WATER QUALITY CONDITIONS

8.1.1 LEWIS AND CLARK LAKE

Water temperature, dissolved oxygen, and turbidity in Lewis and Clark Lake vary temporally, longitudinally (from the dam to the reservoir's upstream reaches), and vertically (from the reservoir's surface to the bottom). During periods of calm weather in the summer, Lewis and Clark Lake develops a slight thermal stratification. When this slight stratification occurs, a thermocline is present at about 8 meters depth. This indicates the reservoir is probably polymixic. The thermal stratification breaks down under windier conditions, given the shallow depth of the reservoir (i.e., 14 meters), and the reservoir mixes throughout its water column. Parameters that significantly varied from the surface to the bottom of the reservoir at the near-dam, deepwater location included water temperature, dissolved oxygen, ORP, pH, alkalinity, total organic carbon, total ammonia, and total phosphorus. The dominant algal group sampled in the reservoir was Bacillariophyta (i.e., Diatoms). The dominant zooplankton sampled in the reservoir were Cladocerans and Copepods. Monitoring indicated that the lacustrine zone of Lewis and Clark Lake is currently in a eutrophic state.

Water quality monitoring of the existing conditions of Lewis and Clark Lake indicated a possible water quality concern regarding nutrients. The Nebraska "nutrient criteria" for total phosphorus and chlorophyll *a* applicable to Lewis and Clark Lake were regularly exceeded throughout the reservoir and exceed Section 303(d) impairment listing criteria identified by the State of Nebraska for the protection of aquatic life. It is also noted that the estimated loss of 24.3 percent of the "as-built" multi-purpose pool volume of Lewis and Clark Lake is approaching Nebraska's impairment identification criterion of 25 percent volume loss.

8.1.2 MISSOURI RIVER DOWNSTREAM OF GAVINS POINT DAM

Water quality monitoring of the existing conditions of the Gavins Point Dam discharge and tailwaters did not indicate any water quality concerns in the Missouri River. There appeared to be little correlation between dam discharge rates and measured water temperature and dissolved oxygen concentrations. Inflow temperatures of the Missouri River to Lewis and Clark Lake tend to be at little cooler than the outflow temperatures of Gavins Point Dam during the spring and early summer. Outflow temperatures of the Gavins Point Dam discharge tend to be a little cooler than the Missouri River inflow temperatures in the late-summer and fall.

8.2 WATER QUALITY MANAGEMENT

The Omaha District is planning to pursue the application of the Corps' CE-QUAL-W2 hydrodynamic and water quality model to Lewis and Clark Lake. CE-QUAL-W2 is a powerful tool to aid in addressing reservoir water quality management issues. Application of the CE-QUAL-W2 model will allow the Corps to better understand how the operation of the Gavins Point Project affects the water quality in Lewis and Clark Lake and the dam discharges to the Missouri River. It is almost a certainty that water quality issues at the Gavins Point Project will remain important in the future.

8.3 WATER QUALITY MONITORING RECOMMENDATIONS

Continue monthly (i.e., May, June, July, August, and September) monitoring of ambient water quality conditions in Lewis and Clark at three sites: GPTLK0811A, GPTLK819DW, and GPTLK0825DW. Continue monthly (i.e., April, May, June, July, August, and September) monitoring of inflow conditions of the Missouri River near Running Water, South Dakota (i.e., site GPTNFMORR1). Continue year-round monitoring (i.e., monthly water samples and hourly data-logging) of water drawn from the raw-water supply line at the Gavins Point powerplant (i.e. site GPTPP1) to represent Missouri River outflow conditions. Continue year-round monthly monitoring of ambient conditions in the Gavins Point Dam tailwaters (i.e., GPTRRTW1).

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10 PLATES

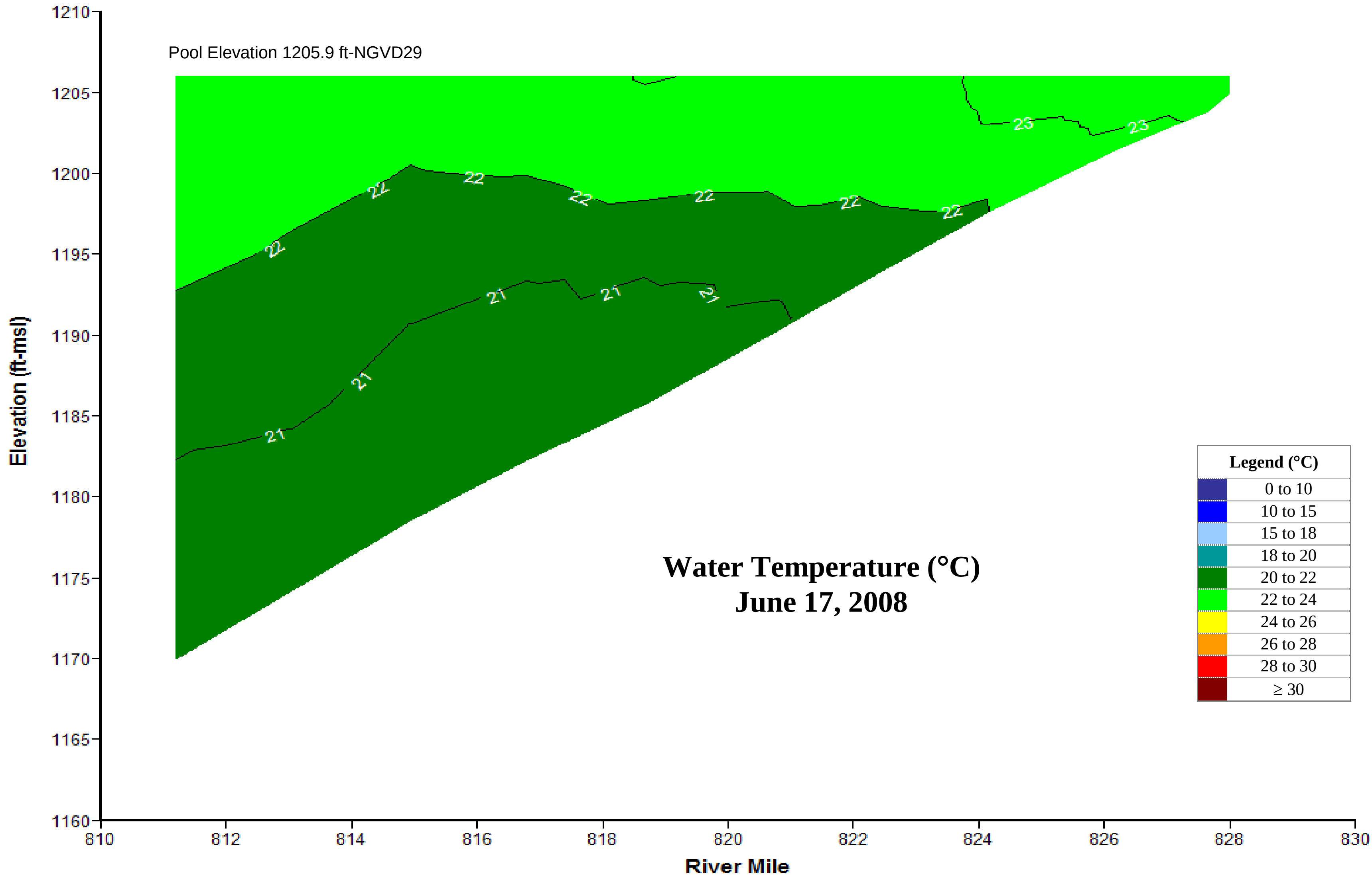

Plate 1. Longitudinal water temperature (°C) contour plot of Lewis and Clark Lake based on depth-profile water temperatures measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on June 17, 2008.

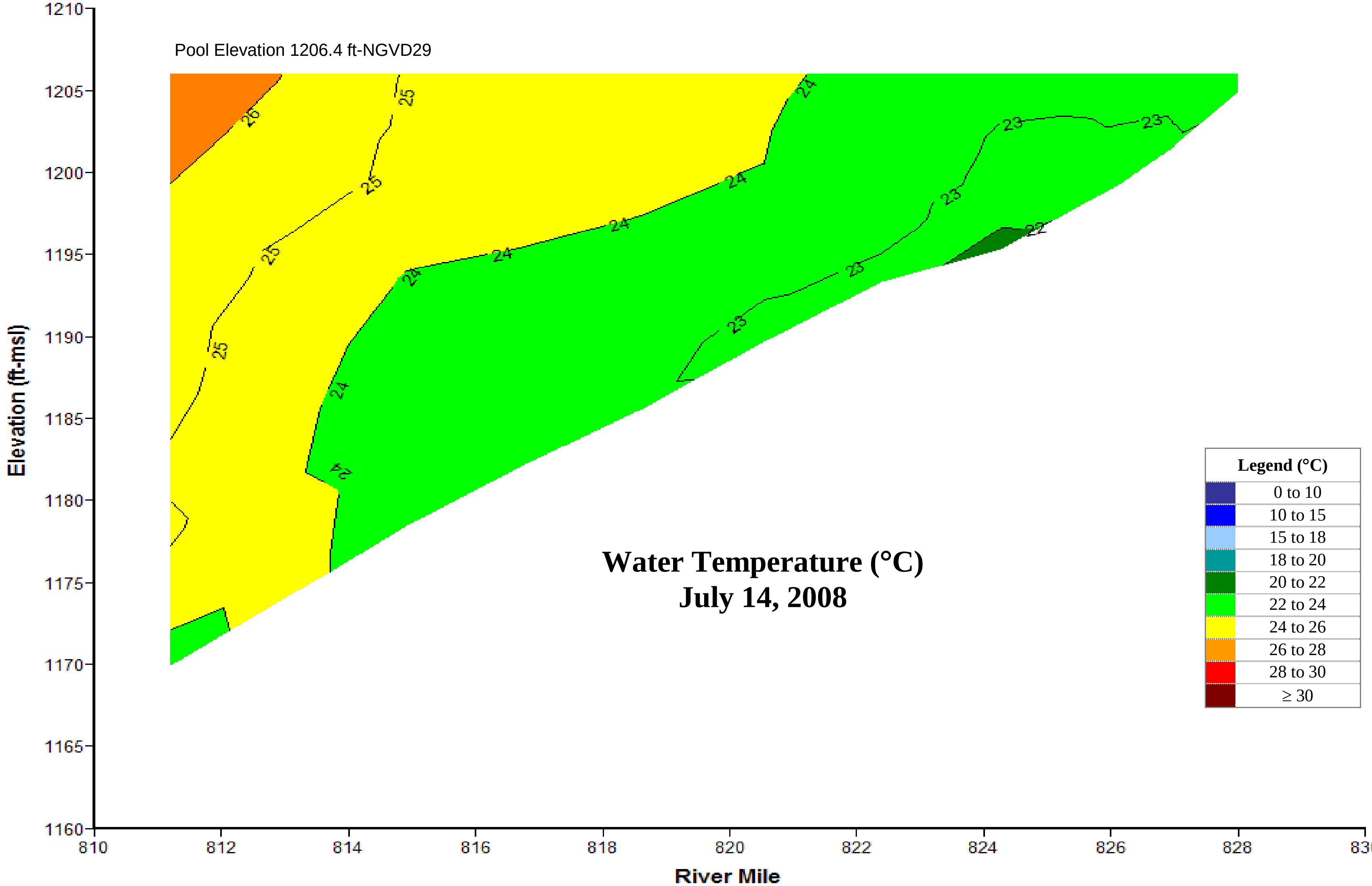

Plate 2. Longitudinal water temperature (°C) contour plot of Lewis and Clark Lake based on depth-profile water temperatures measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on July 14, 2008.

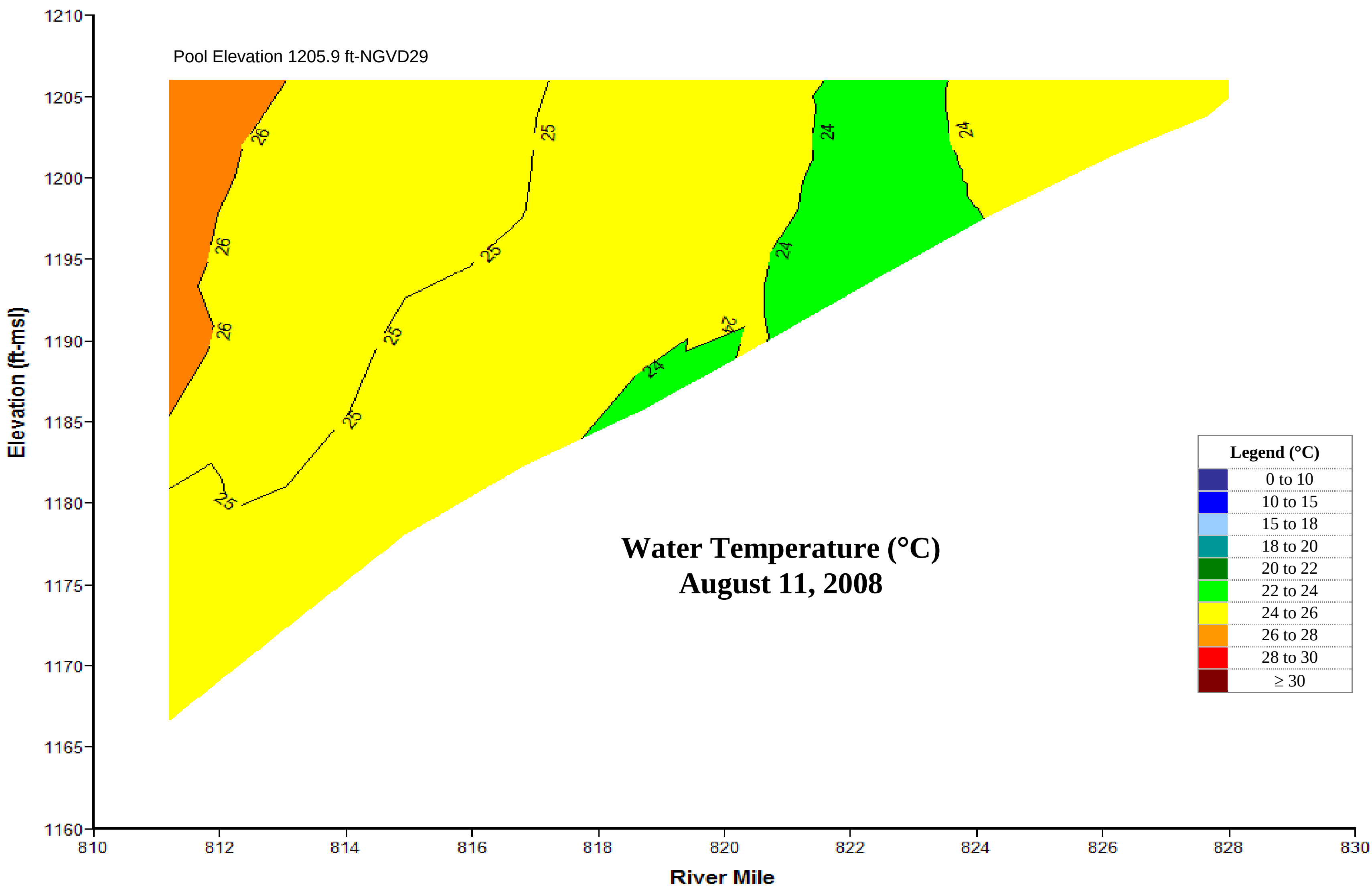

Plate 3. Longitudinal water temperature (°C) contour plot of Lewis and Clark Lake based on depth-profile water temperatures measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on August 11, 2008.

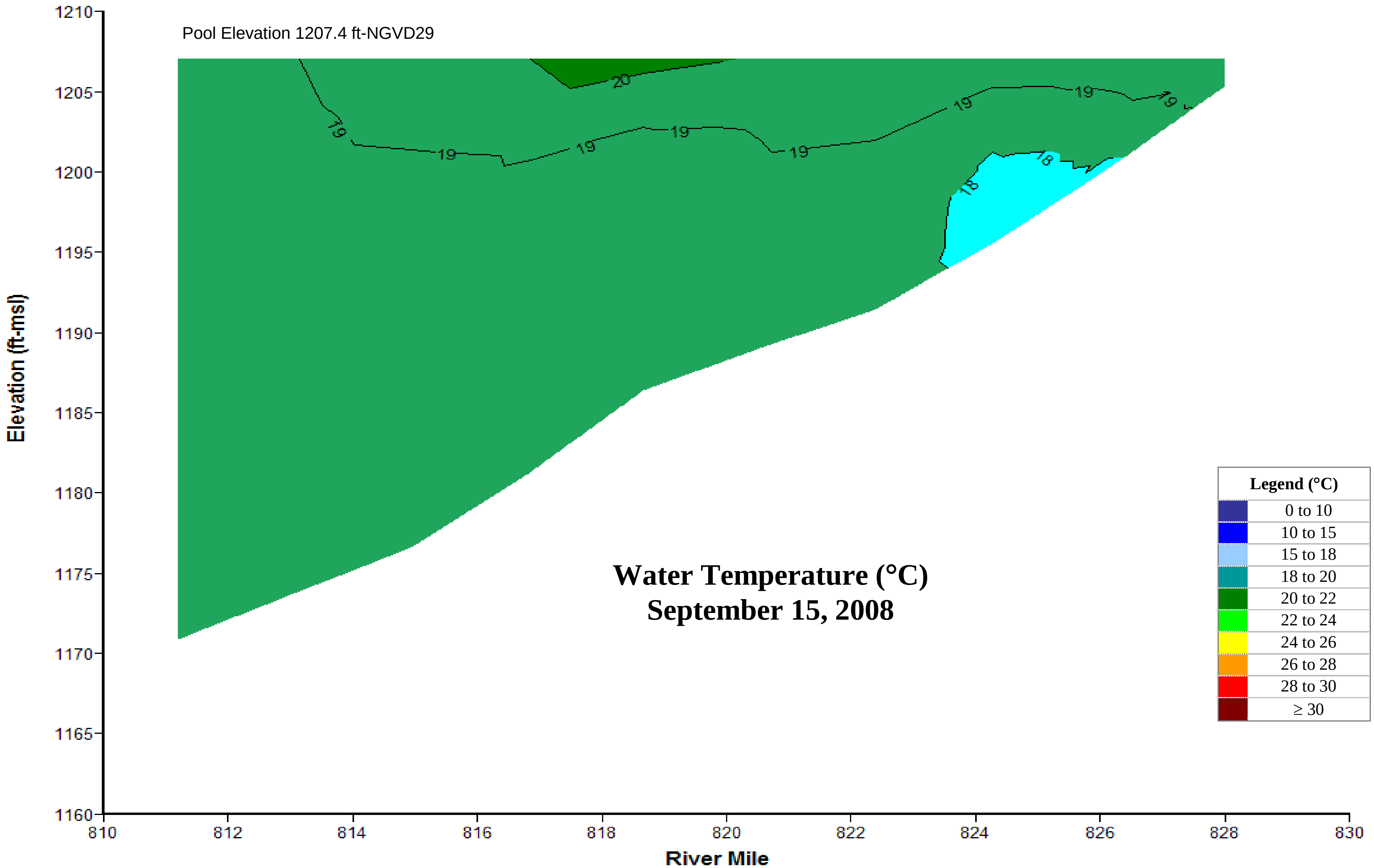

Plate 4. Longitudinal water temperature (°C) contour plot of Lewis and Clark Lake based on depth-profile water temperatures measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on September 15, 2008**.**

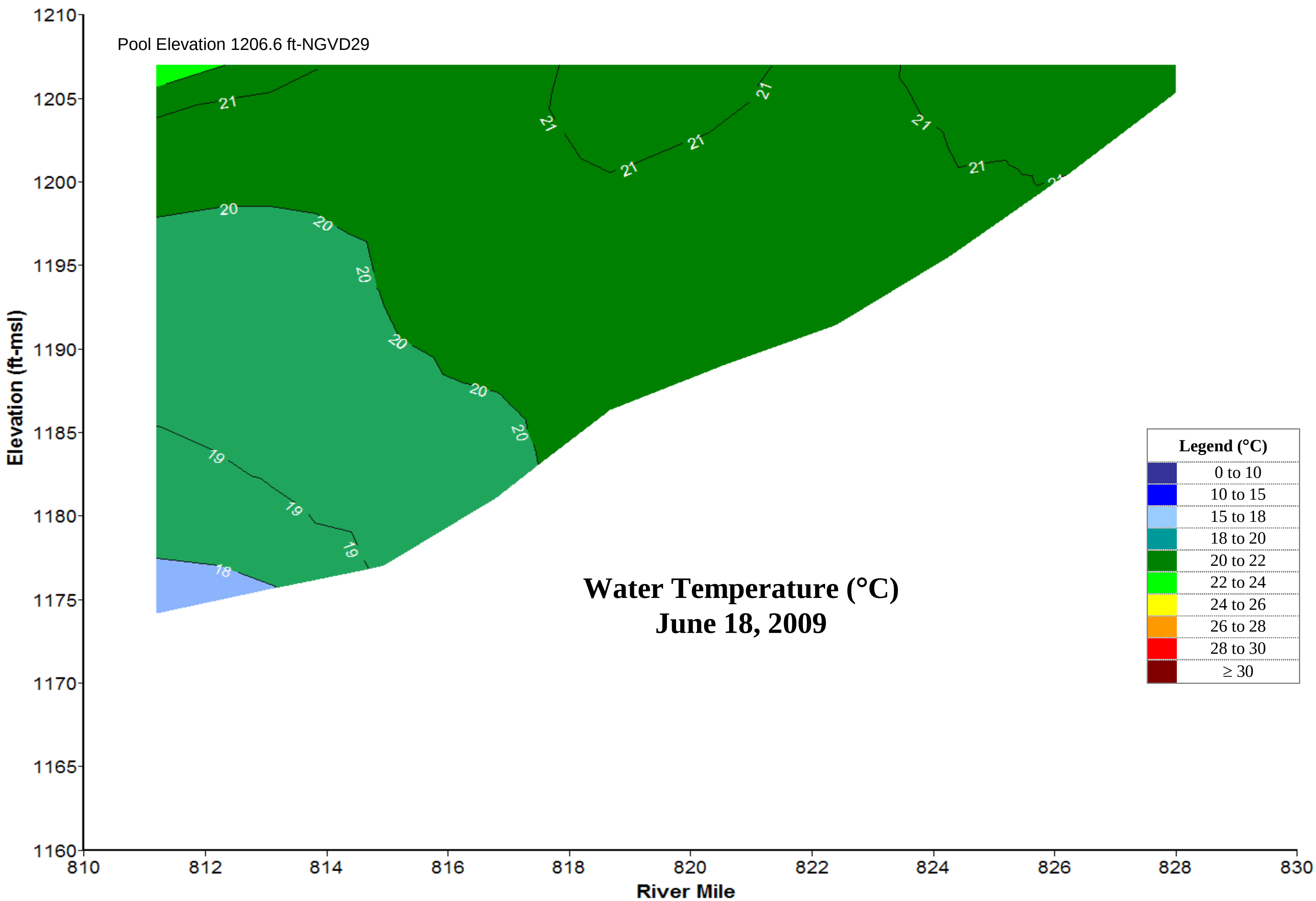

Plate 5. Longitudinal water temperature (°C) contour plot of Lewis and Clark Lake based on depth-profile water temperatures measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on June 18, 2009.

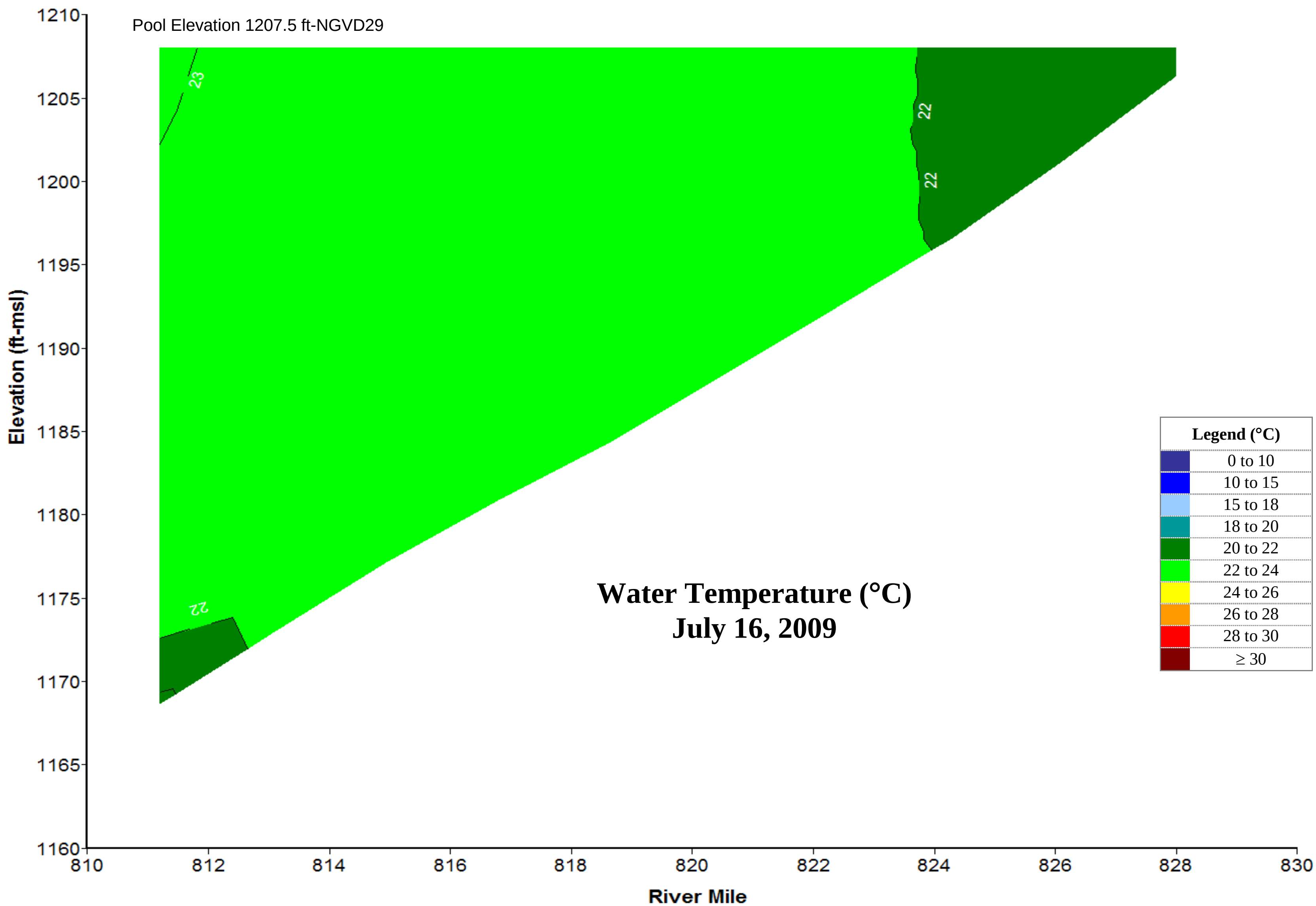

Plate 6. Longitudinal water temperature (°C) contour plot of Lewis and Clark Lake based on depth-profile water temperatures measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on July 16, 2009.

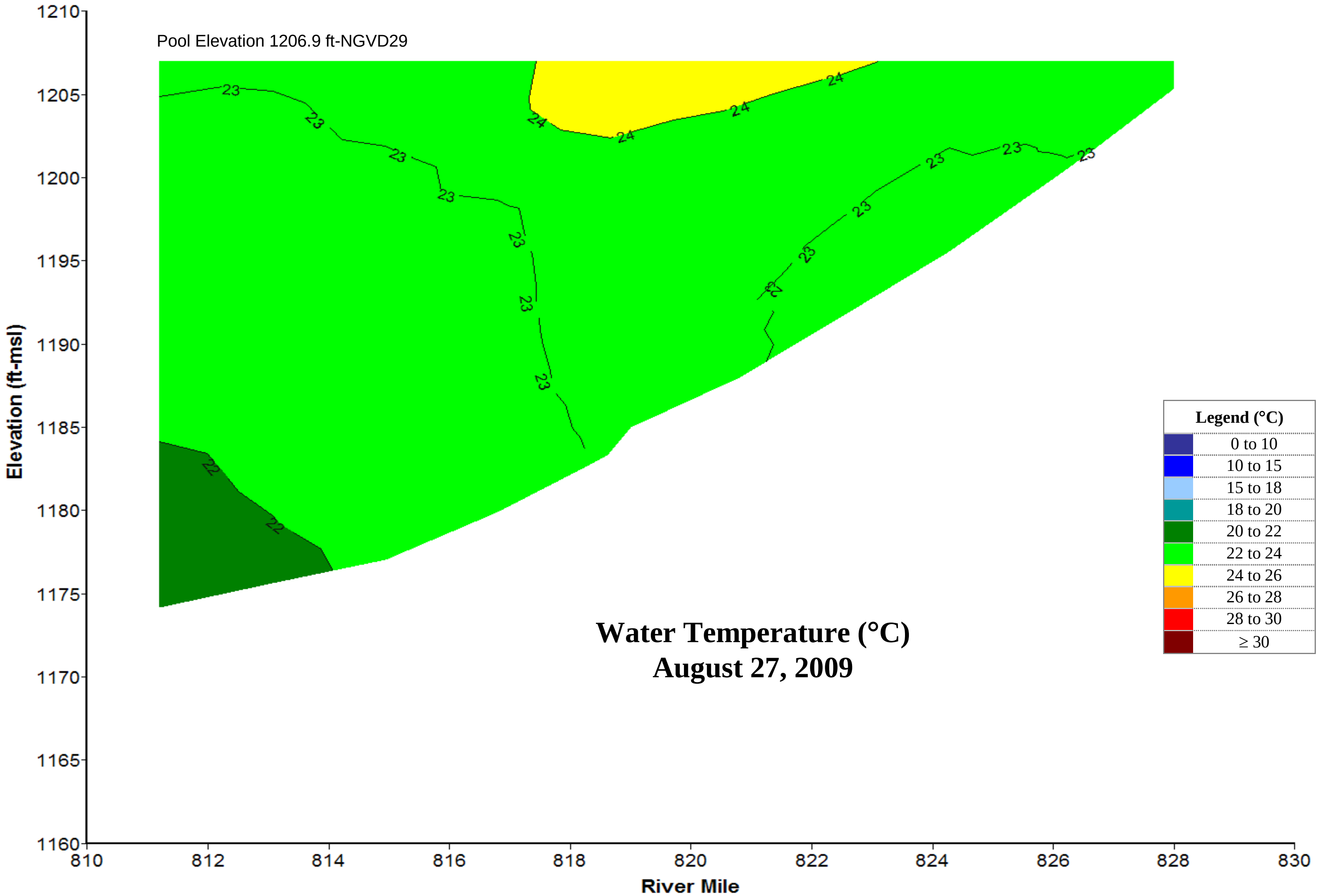

Plate 7. Longitudinal water temperature (°C) contour plot of Lewis and Clark Lake based on depth-profile water temperatures measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on August 27, 2009.

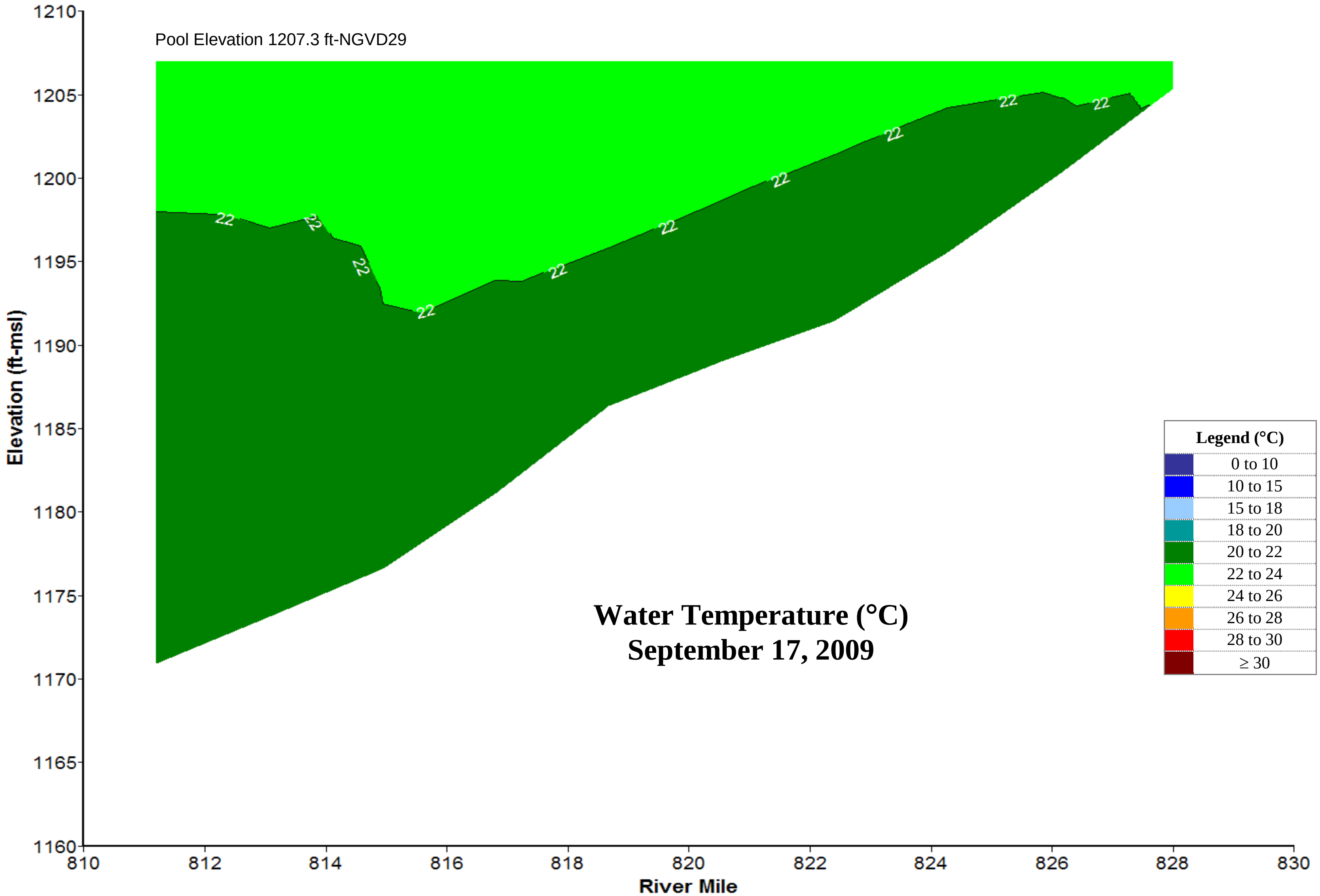

Plate 8. Longitudinal water temperature (°C) contour plot of Lewis and Clark Lake based on depth-profile water temperatures measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on September 17, 2009.

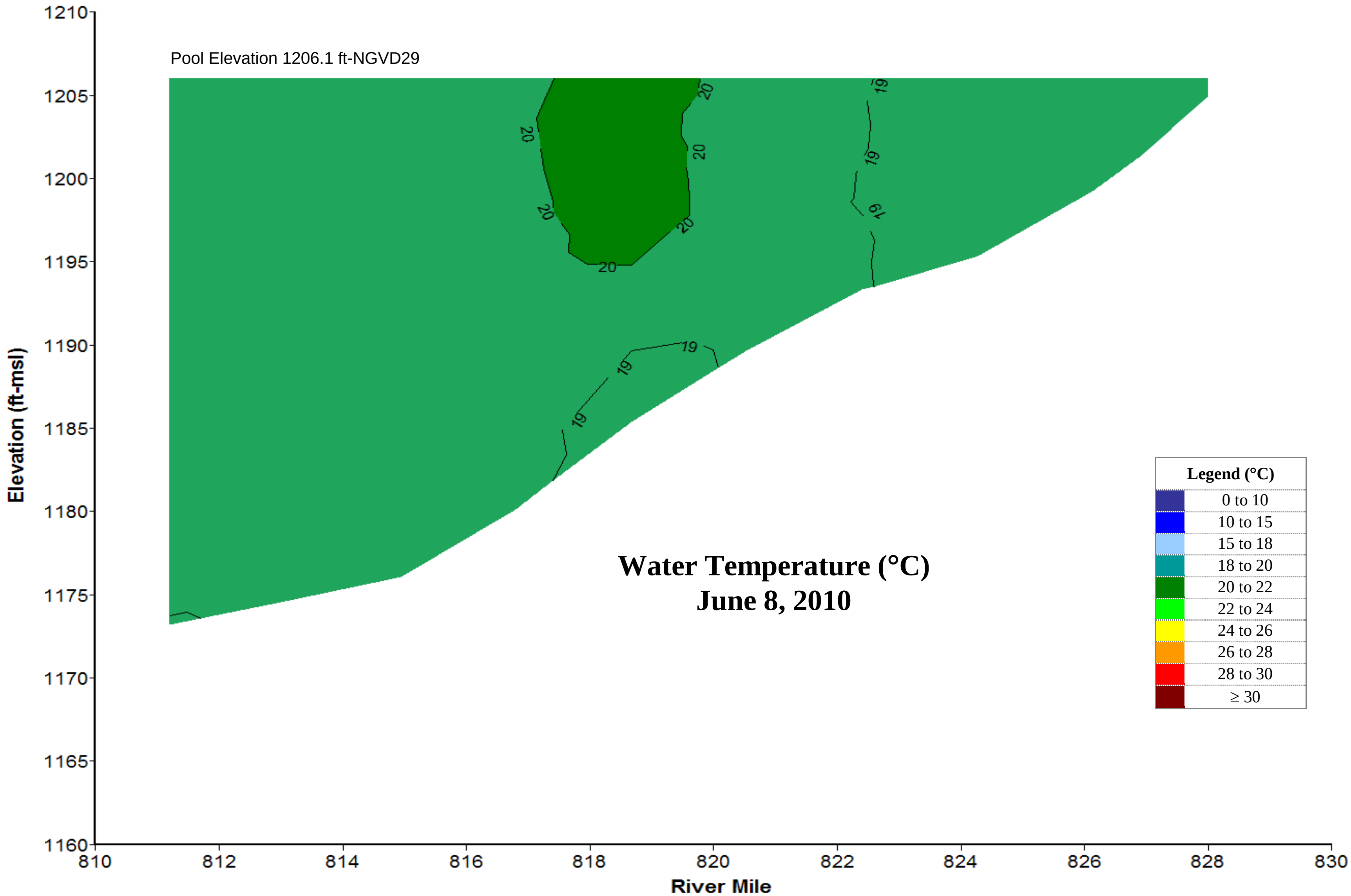

Plate 9. Longitudinal water temperature (°C) contour plot of Lewis and Clark Lake based on depth-profile water temperatures measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on June 8, 2010.

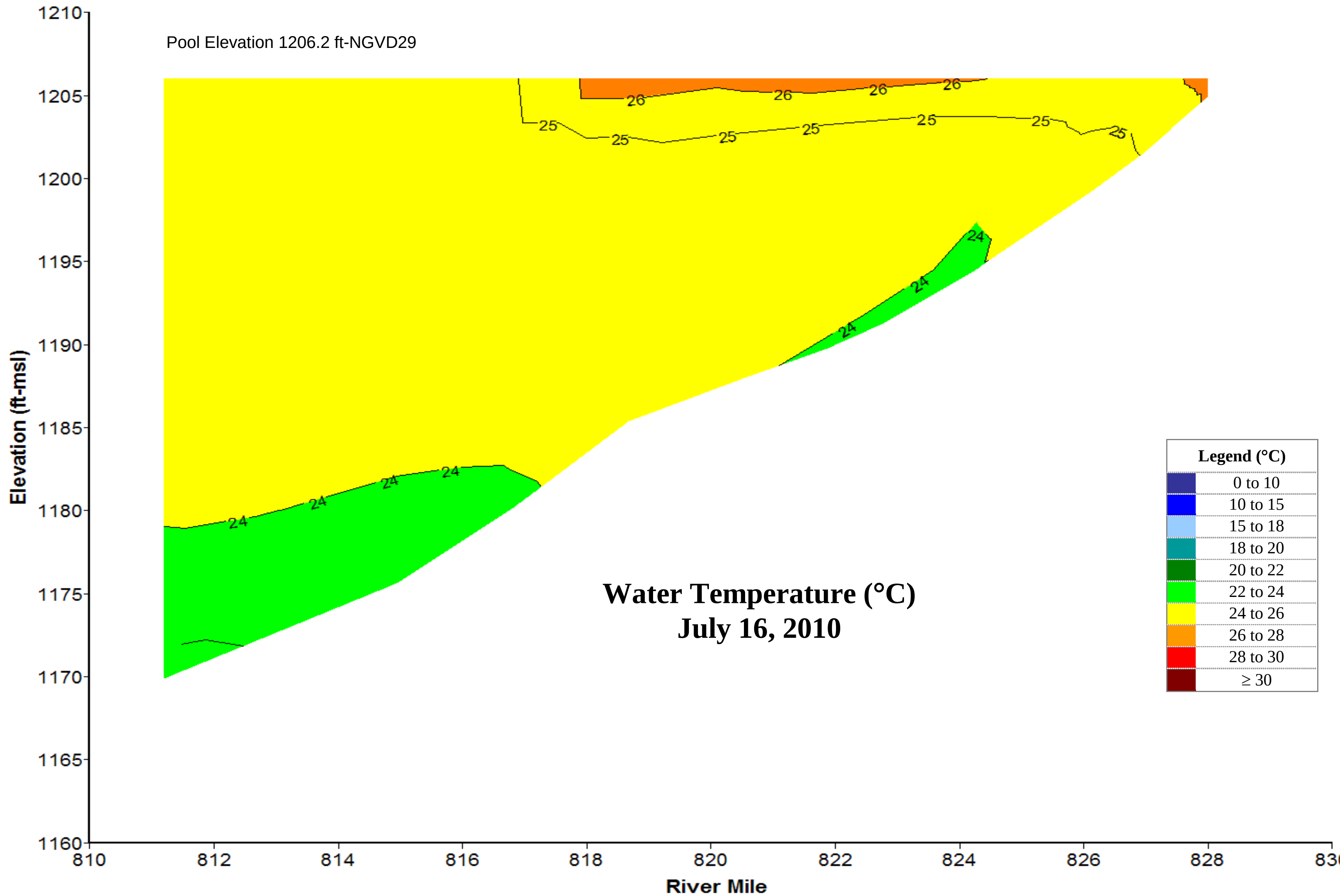

Plate 10. Longitudinal water temperature (°C) contour plot of Lewis and Clark Lake based on depth-profile water temperatures measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on July 16, 2010.

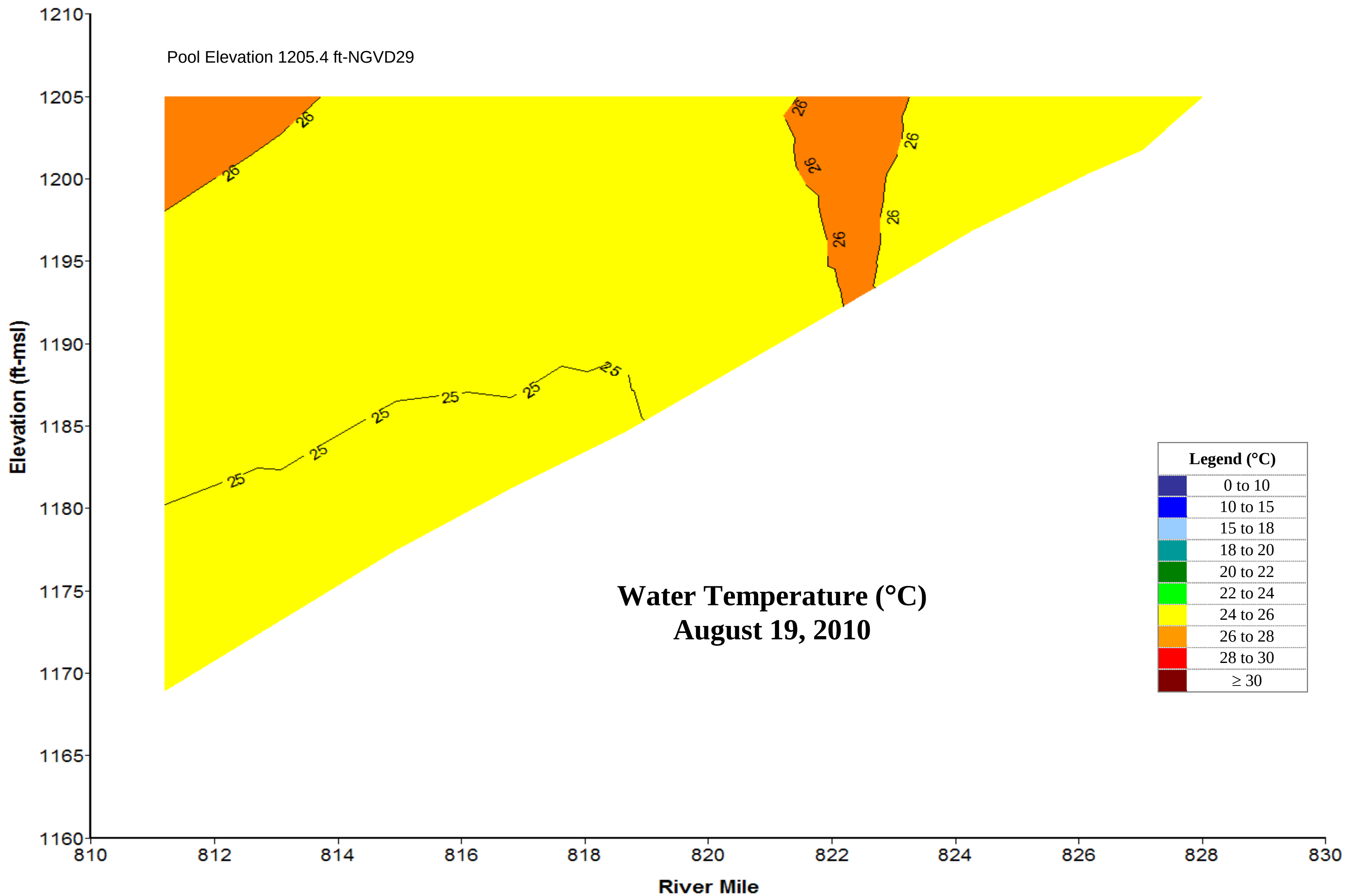

Plate 11. Longitudinal water temperature (°C) contour plot of Lewis and Clark Lake based on depth-profile water temperatures measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on August 19, 2010.

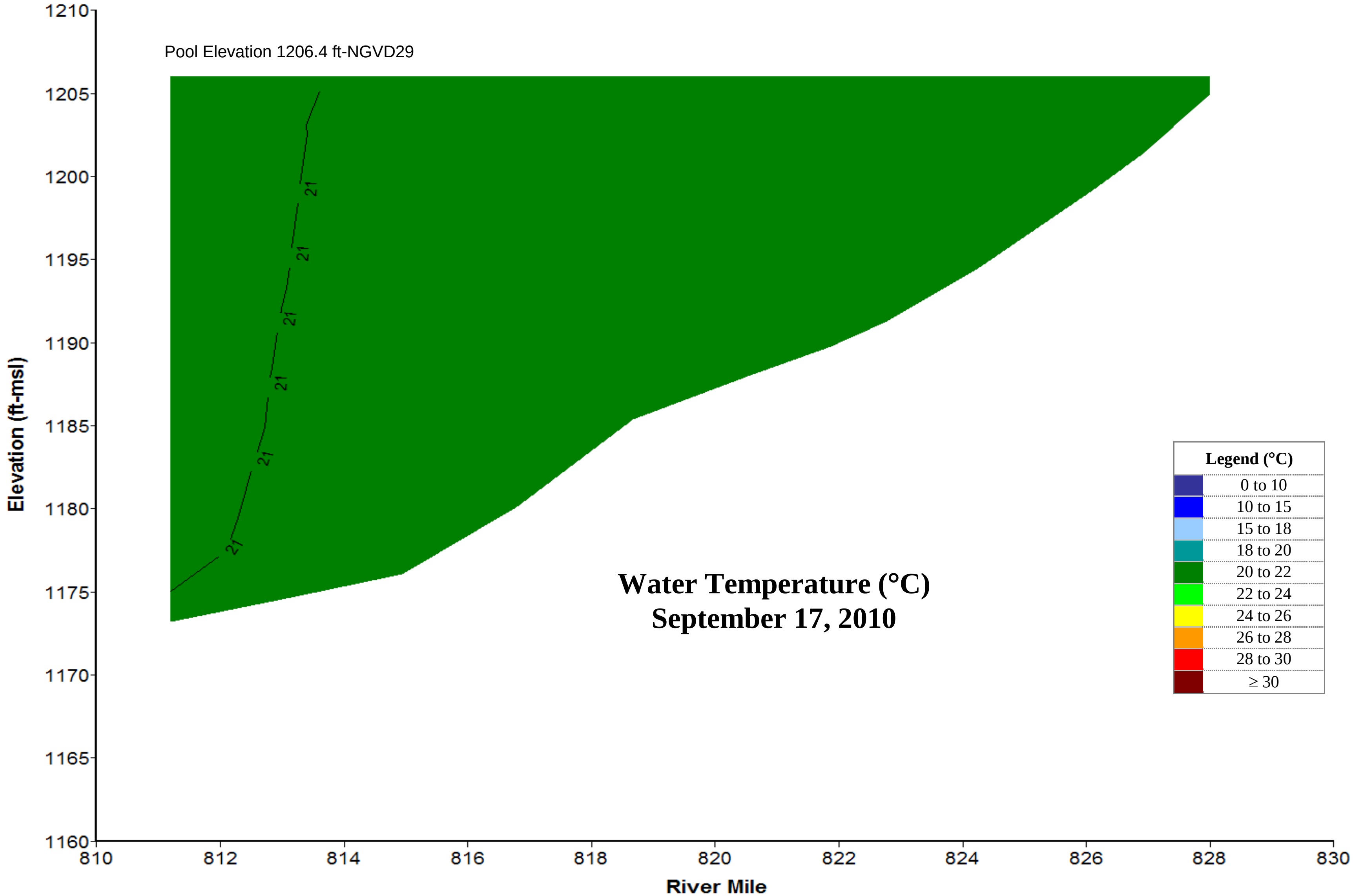

Plate 12. Longitudinal water temperature (°C) contour plot of Lewis and Clark Lake based on depth-profile water temperatures measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on September 17, 2010.

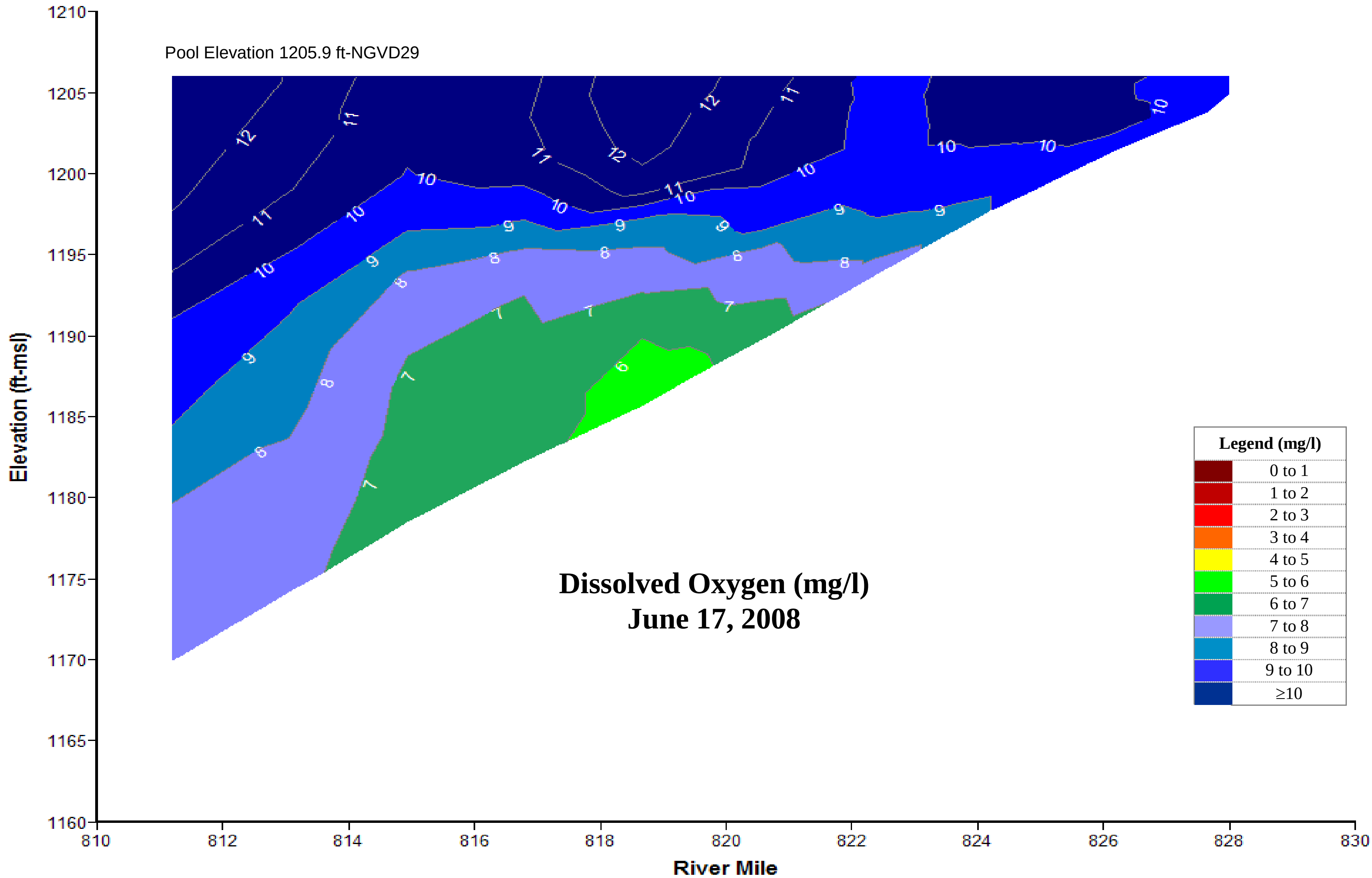

Plate 13. Longitudinal dissolved oxygen (mg/l) contour plot of Lewis and Clark Lake based on depth-profile dissolved oxygen concentrations measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on June 17, 2008.

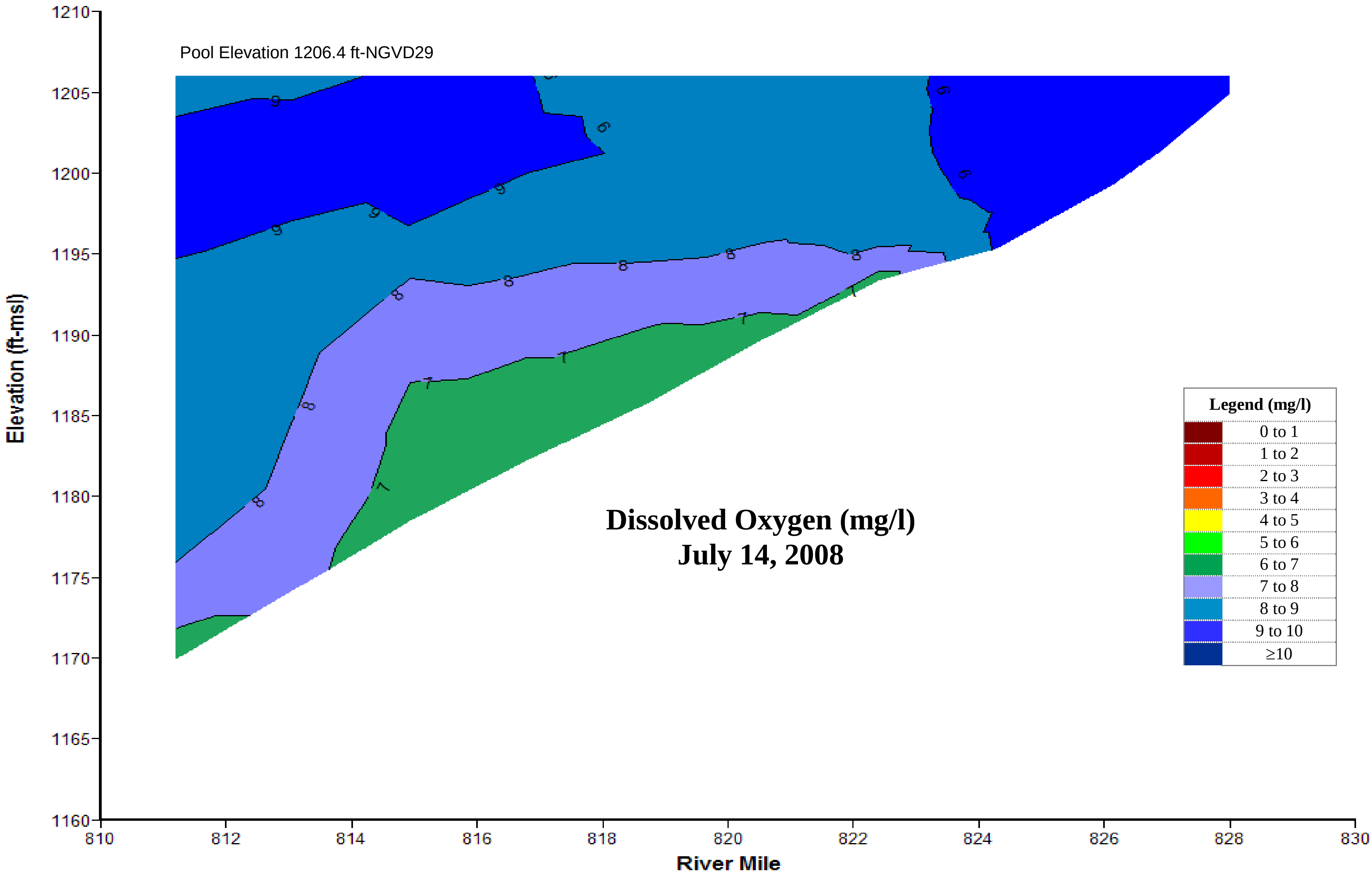

Plate 14. Longitudinal dissolved oxygen (mg/l) contour plot of Lewis and Clark Lake based on depth-profile dissolved oxygen concentrations measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on July 14, 2008.

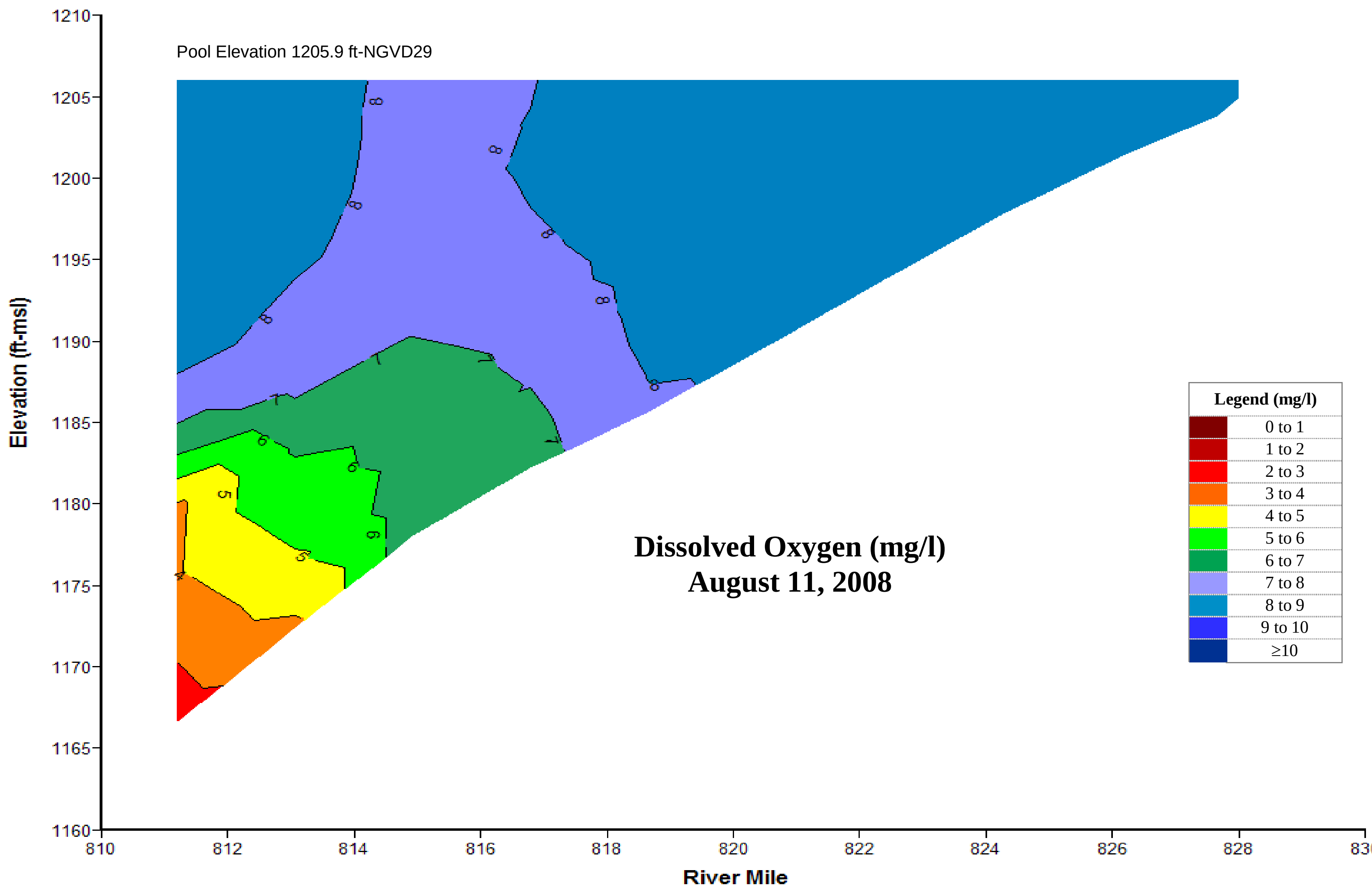

Plate 15. Longitudinal dissolved oxygen (mg/l) contour plot of Lewis and Clark Lake based on depth-profile dissolved oxygen concentrations measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on August 11, 2008.

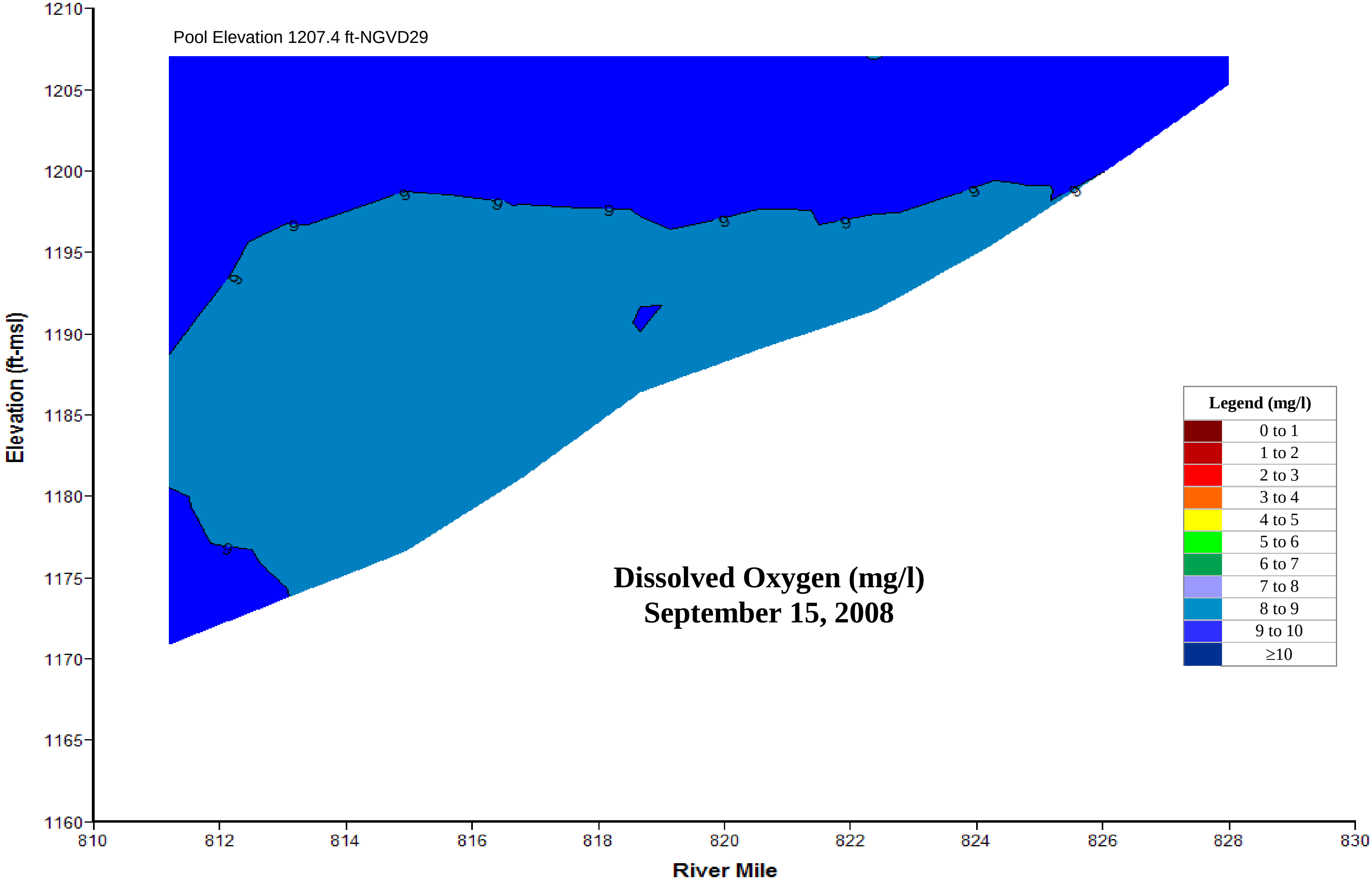

Plate 16. Longitudinal dissolved oxygen (mg/l) contour plot of Lewis and Clark Lake based on depth-profile dissolved oxygen concentrations measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on September 15, 2008.

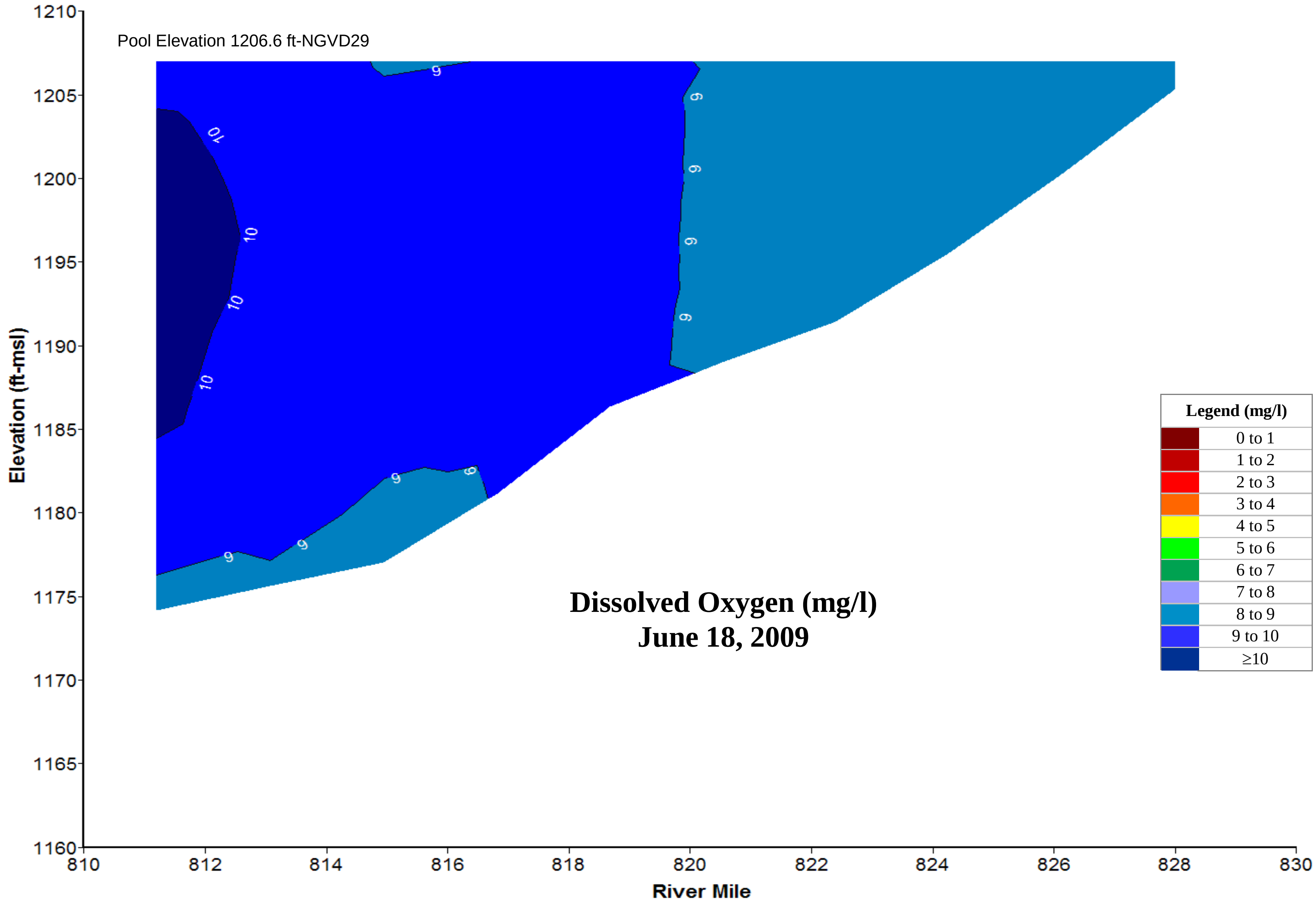

Plate 17. Longitudinal dissolved oxygen (mg/l) contour plot of Lewis and Clark Lake based on depth-profile dissolved oxygen concentrations measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on June 18, 2009.

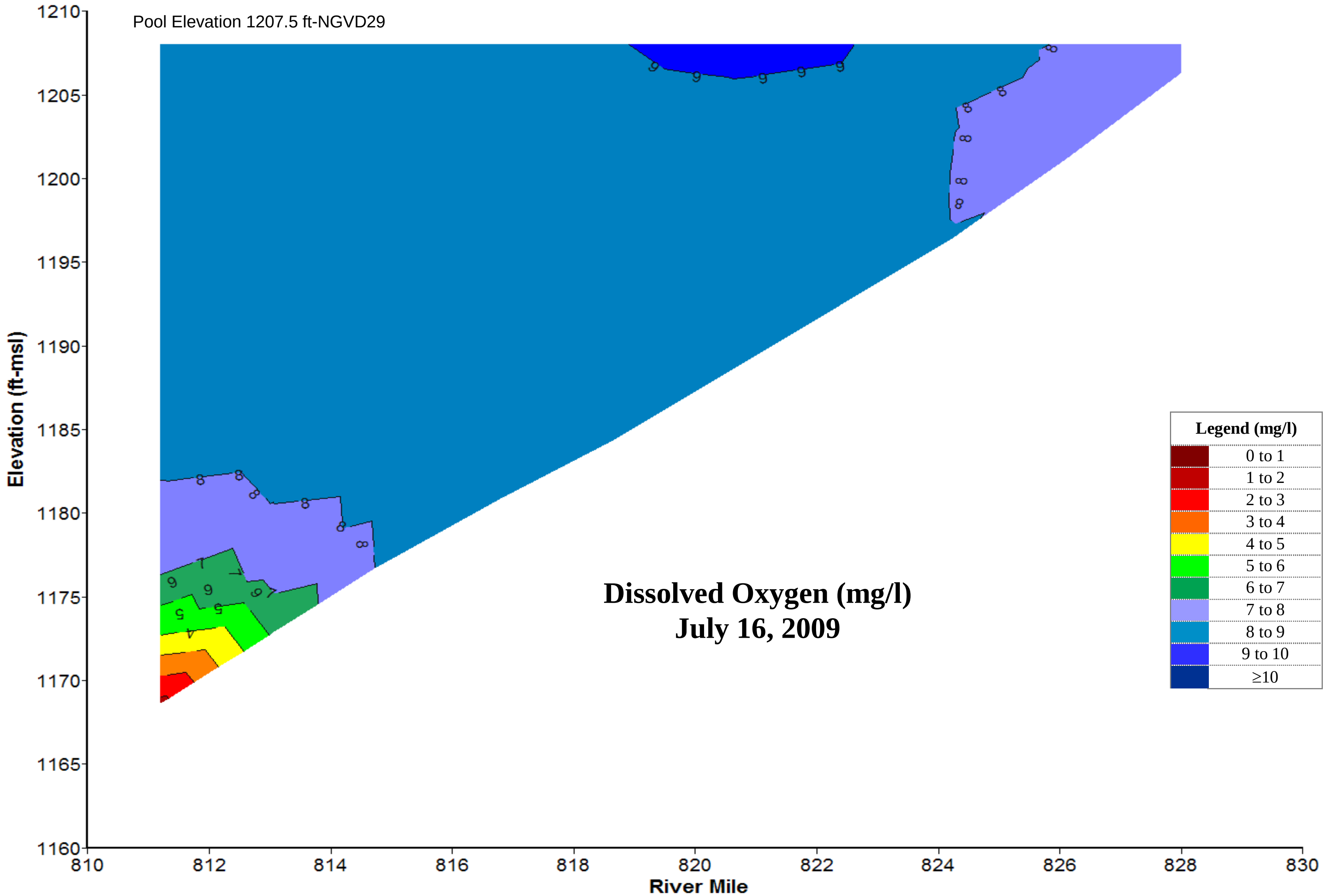

Plate 18. Longitudinal dissolved oxygen (mg/l) contour plot of Lewis and Clark Lake based on depth-profile dissolved oxygen concentrations measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on July 16, 2009.

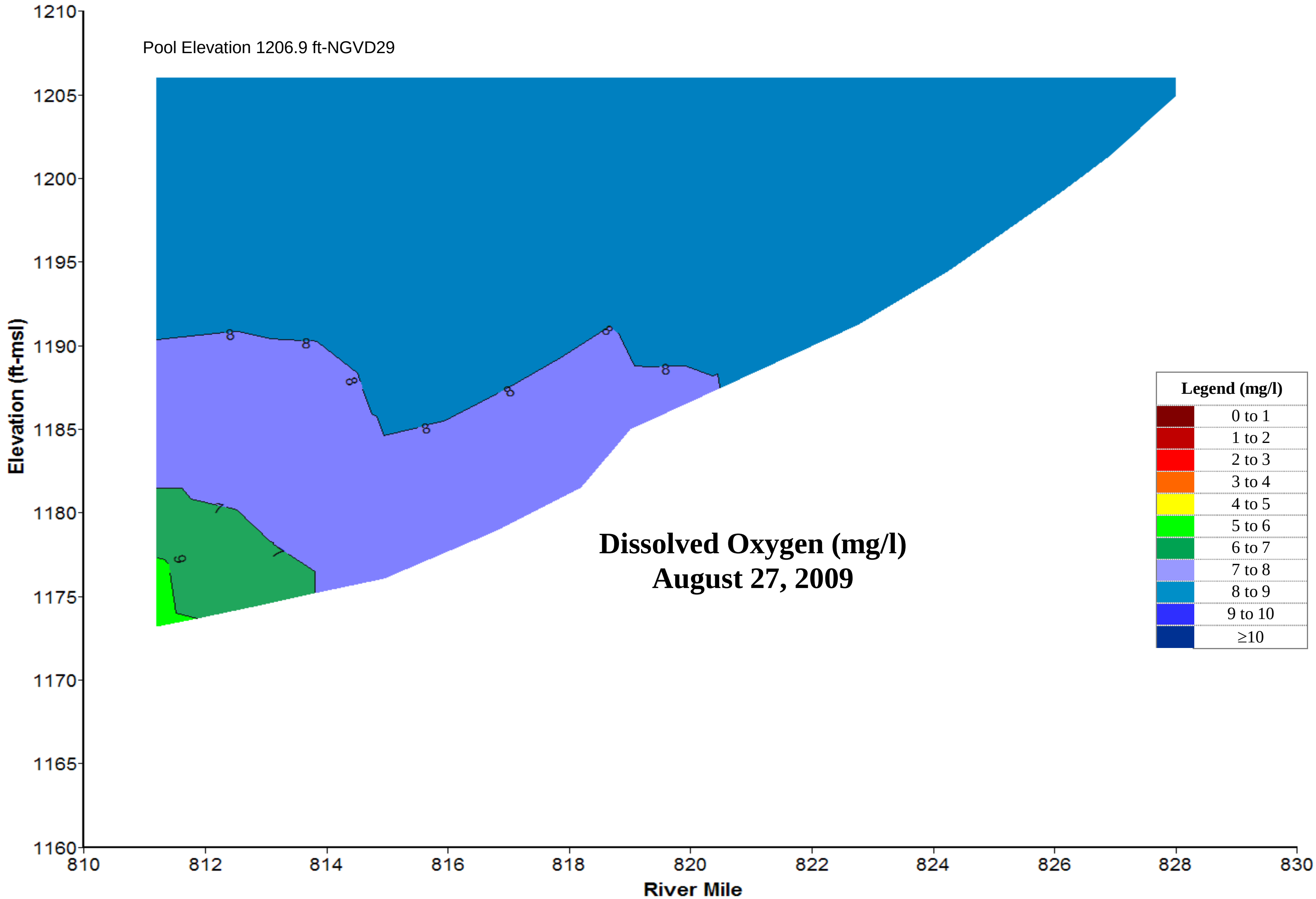

Plate 19. Longitudinal dissolved oxygen (mg/l) contour plot of Lewis and Clark Lake based on depth-profile dissolved oxygen concentrations measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on August 27, 2009.

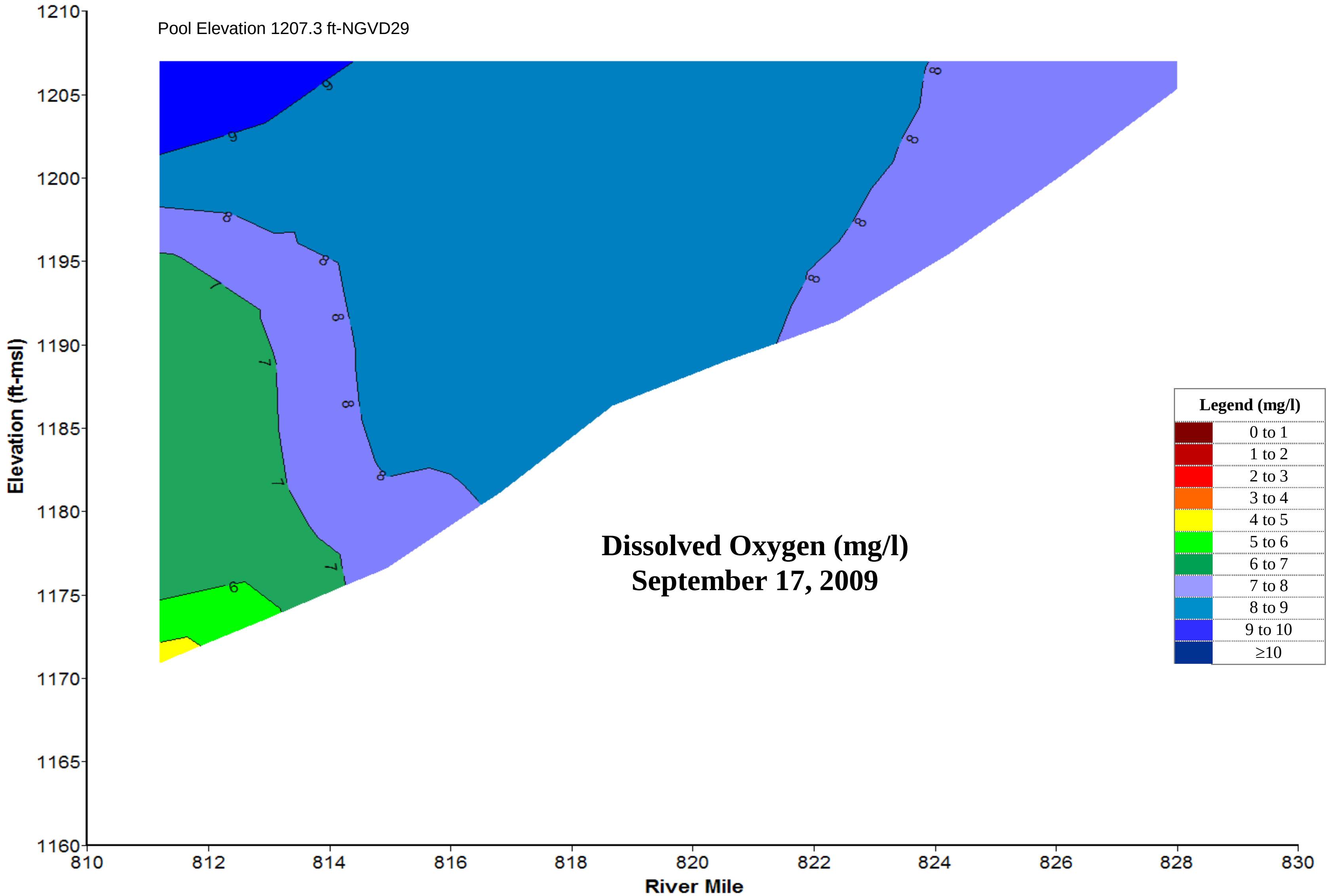

Plate 20. Longitudinal dissolved oxygen (mg/l) contour plot of Lewis and Clark Lake based on depth-profile dissolved oxygen concentrations measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on September 17, 2009.

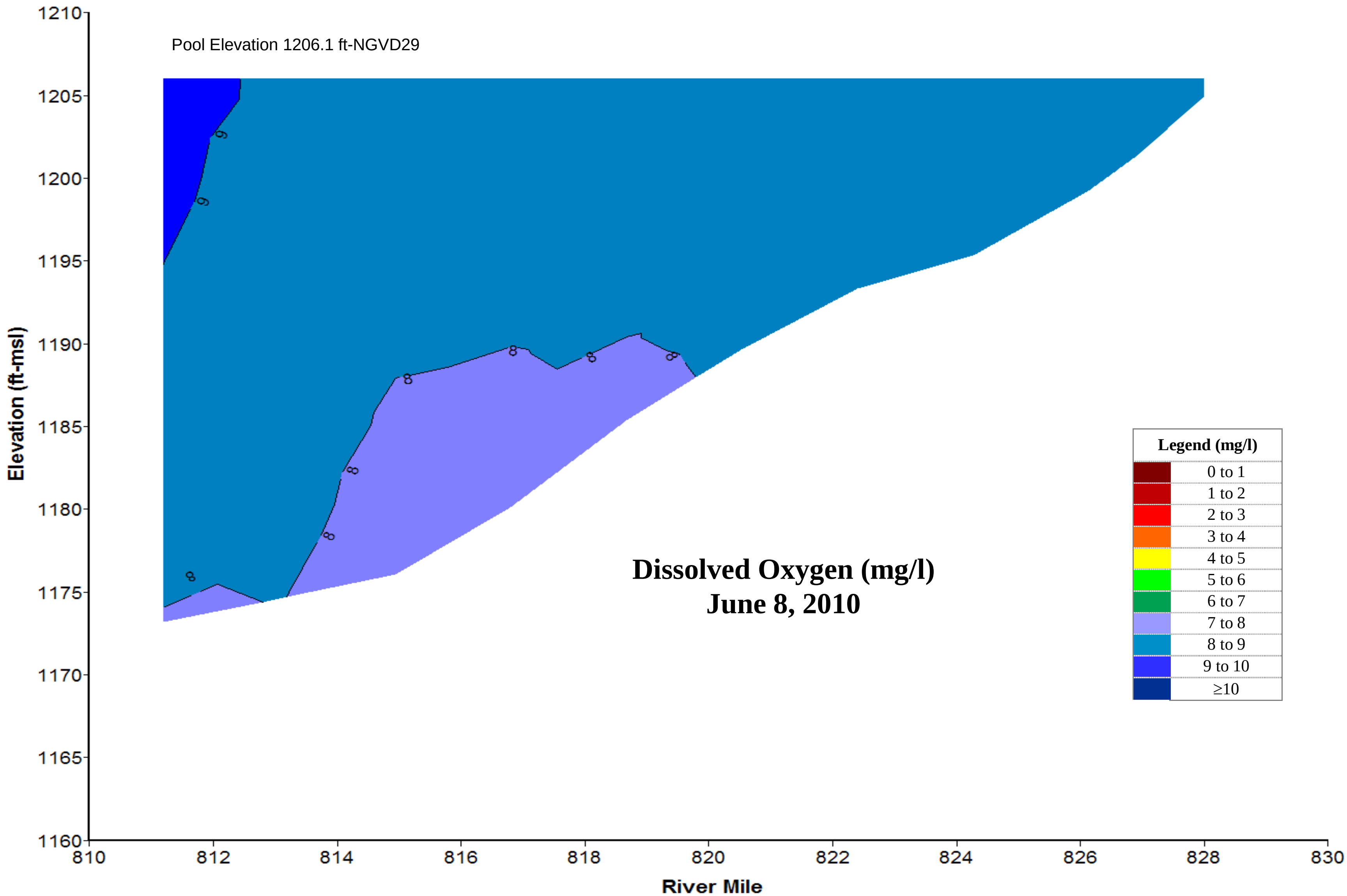

Plate 21. Longitudinal dissolved oxygen (mg/l) contour plot of Lewis and Clark Lake based on depth-profile dissolved oxygen concentrations measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on June 8, 2010.

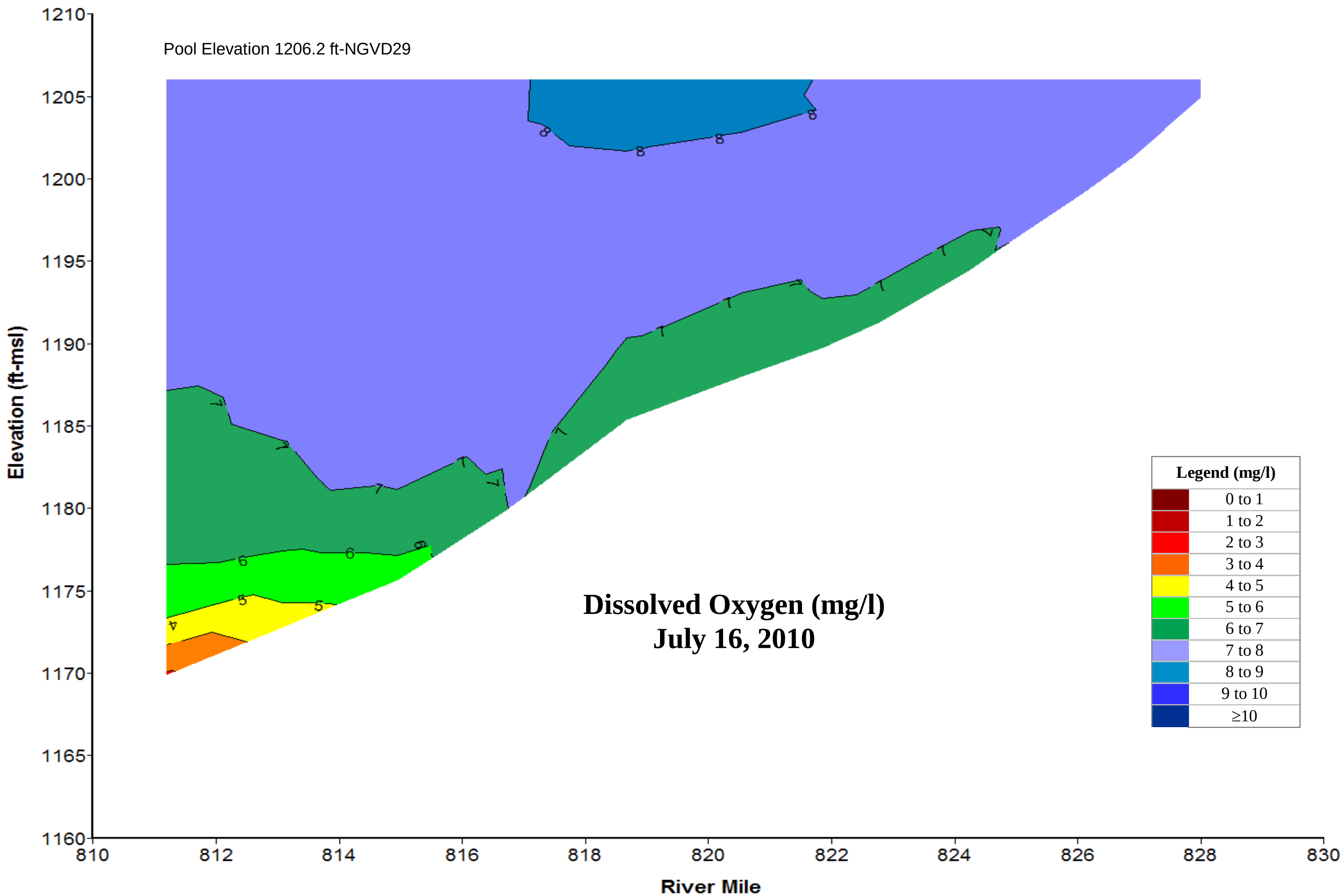

Plate 22. Longitudinal dissolved oxygen (mg/l) contour plot of Lewis and Clark Lake based on depth-profile dissolved oxygen concentrations measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on July 16, 2010.

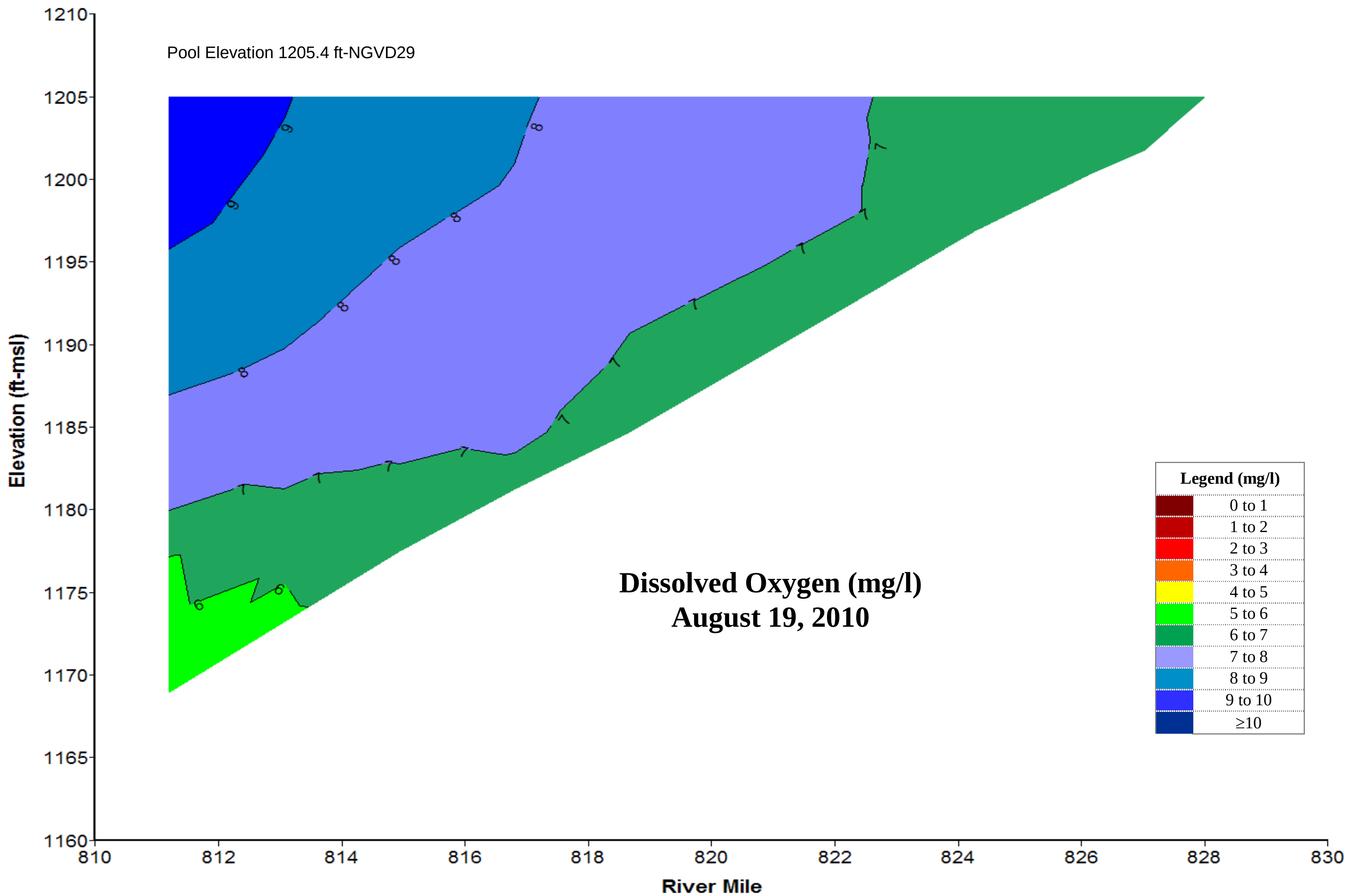

Plate 23. Longitudinal dissolved oxygen (mg/l) contour plot of Lewis and Clark Lake based on depth-profile dissolved oxygen concentrations measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on August 19, 2010.

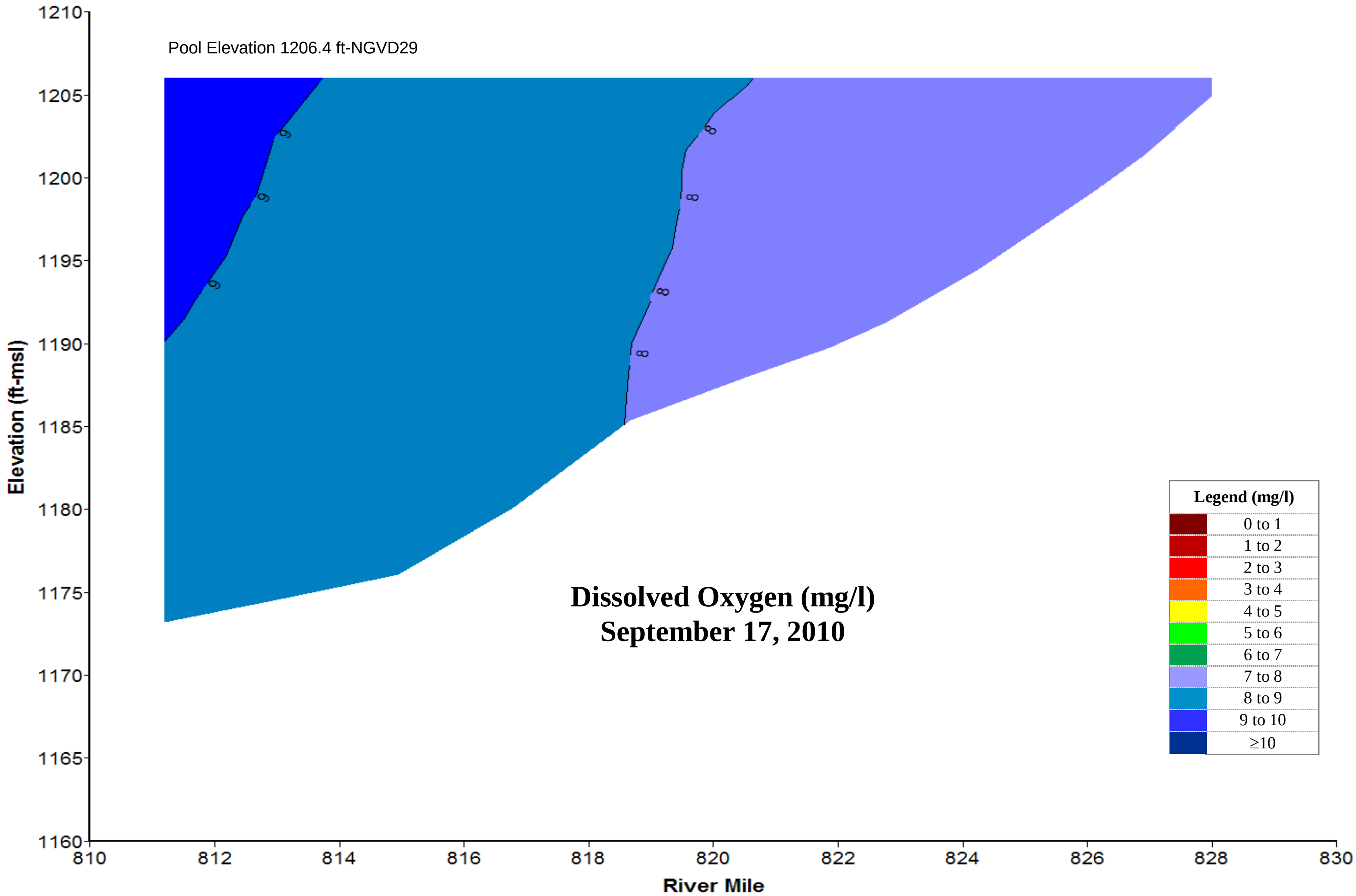

Plate 24. Longitudinal dissolved oxygen (mg/l) contour plot of Lewis and Clark Lake based on depth-profile dissolved oxygen concentrations measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on September 17, 2010.

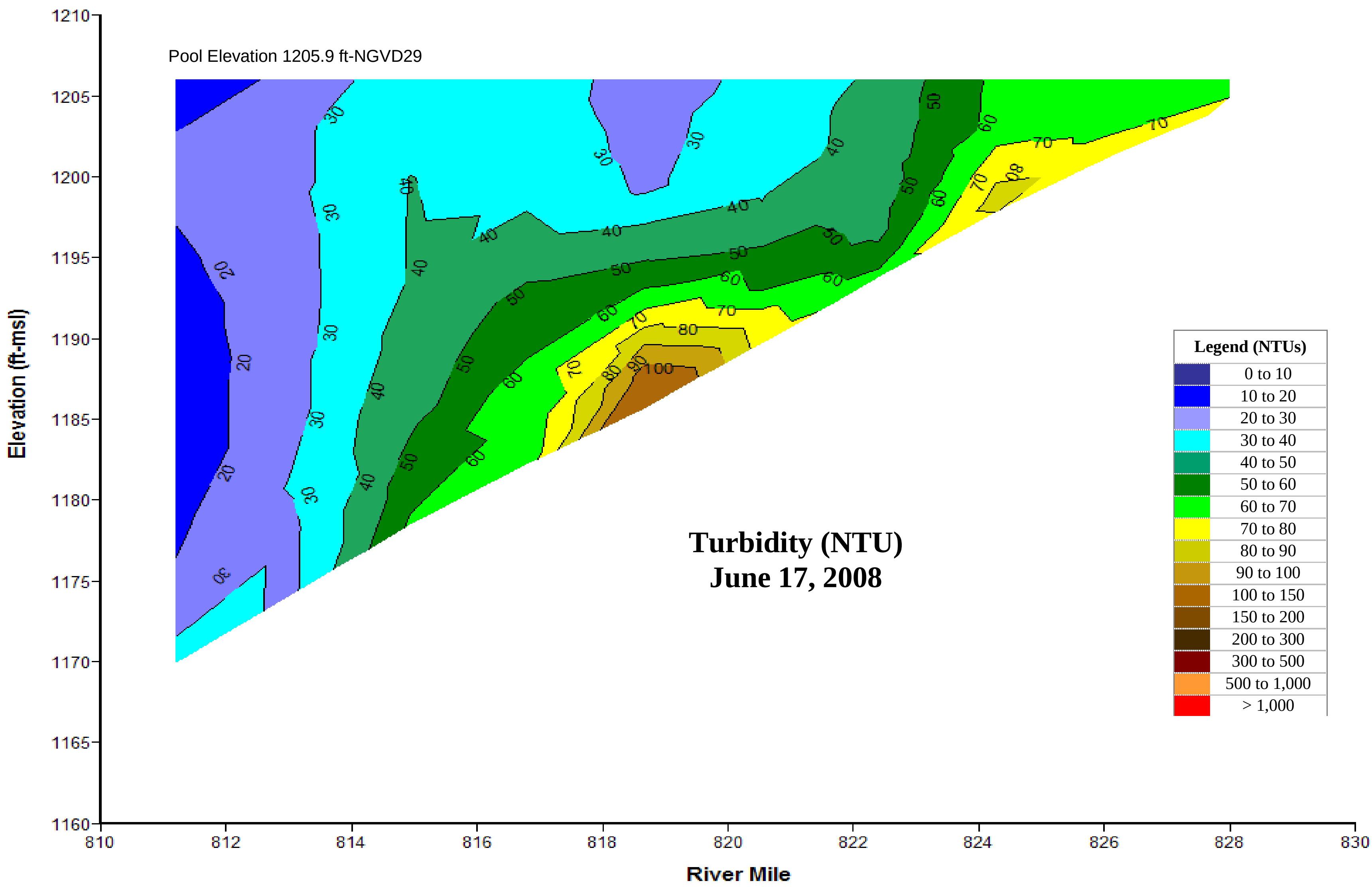

Plate 25. Longitudinal turbidity (NTUs) contour plot of Lewis and Clark Lake based on depth-profile turbidity levels measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on June 17, 2008.

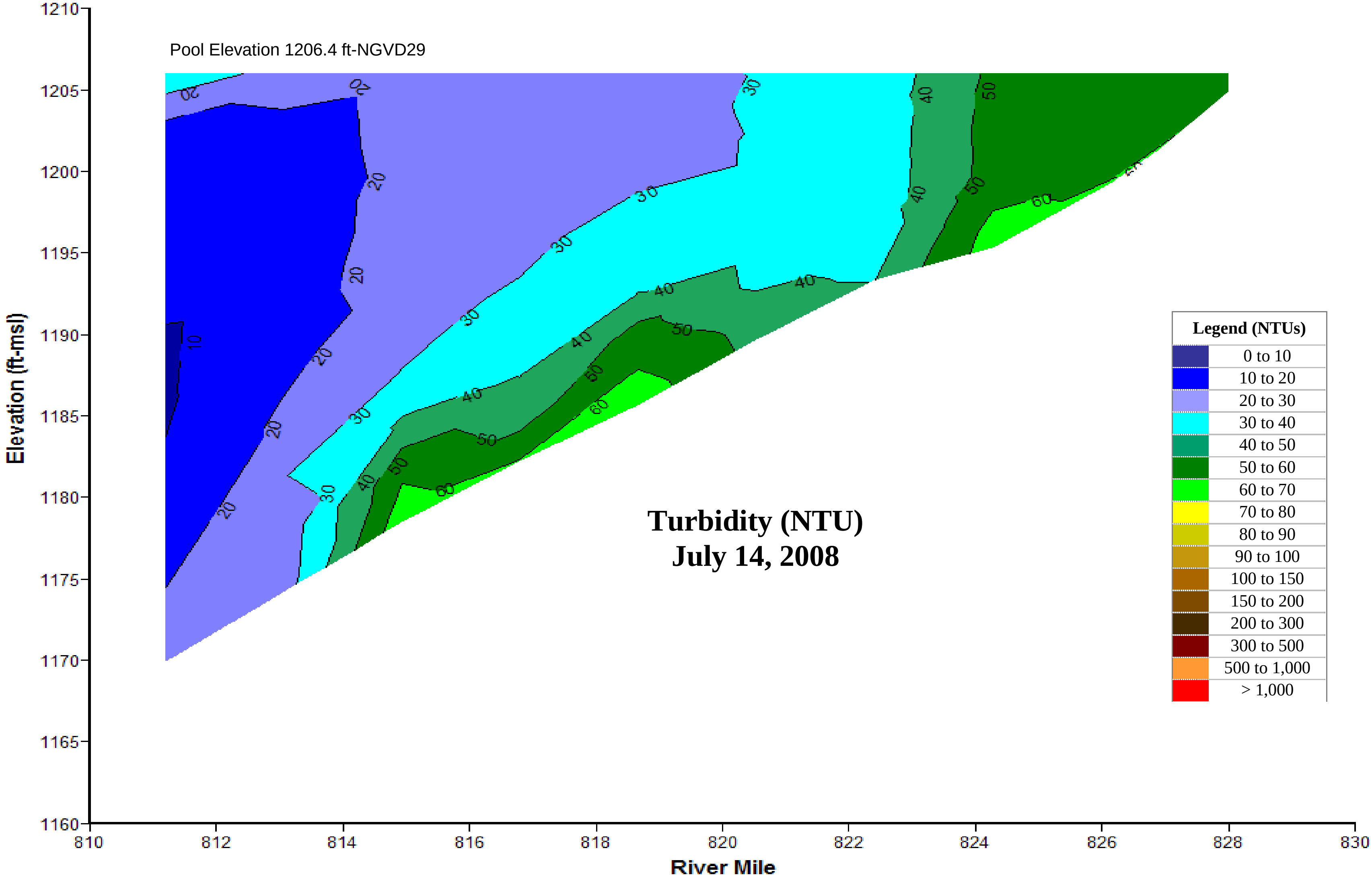

Plate 26. Longitudinal turbidity (NTUs) contour plot of Lewis and Clark Lake based on depth-profile turbidity levels measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on July 14, 2008.

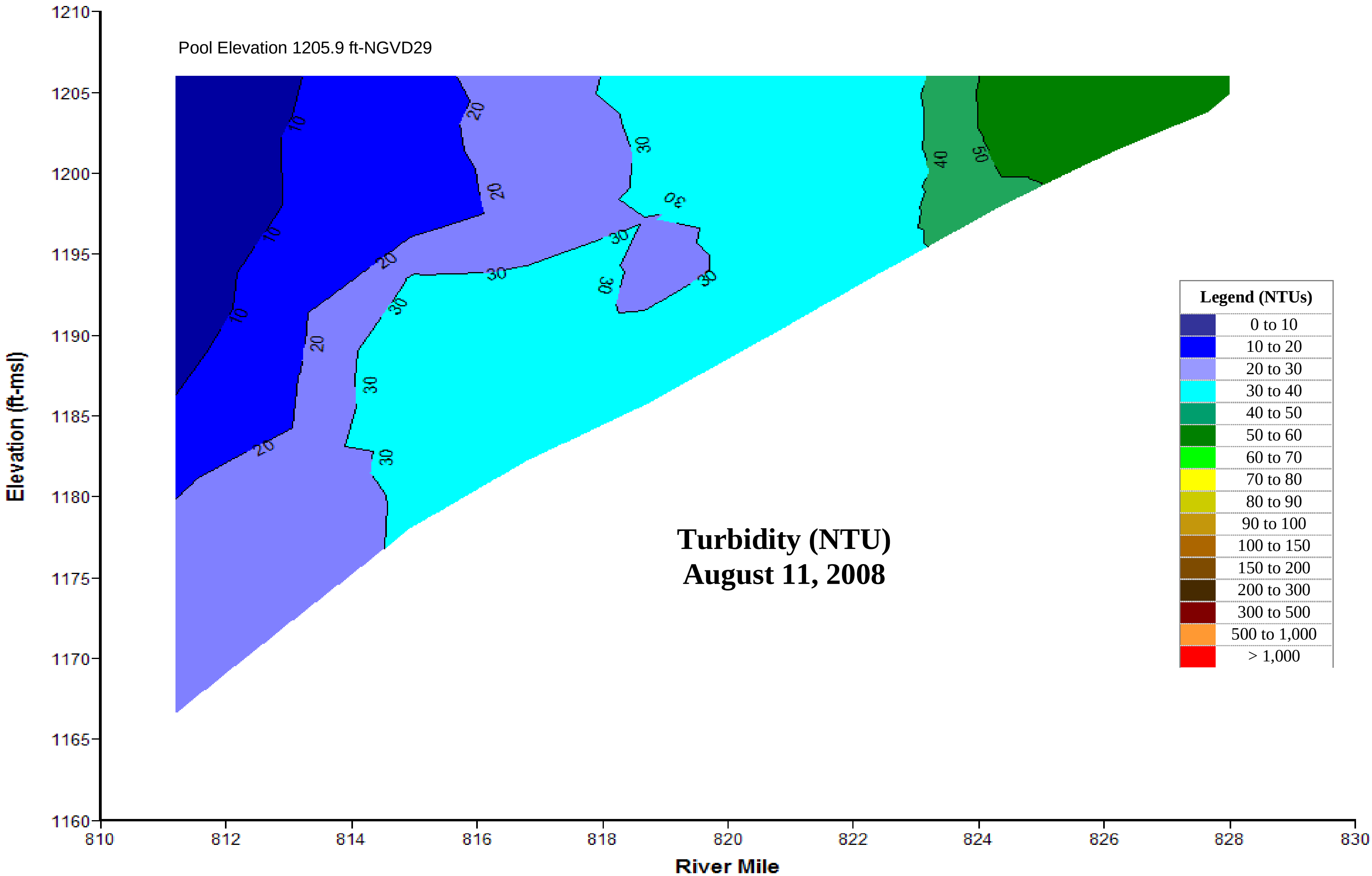

Plate 27. Longitudinal turbidity (NTUs) contour plot of Lewis and Clark Lake based on depth-profile turbidity levels measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on August 11, 2008.

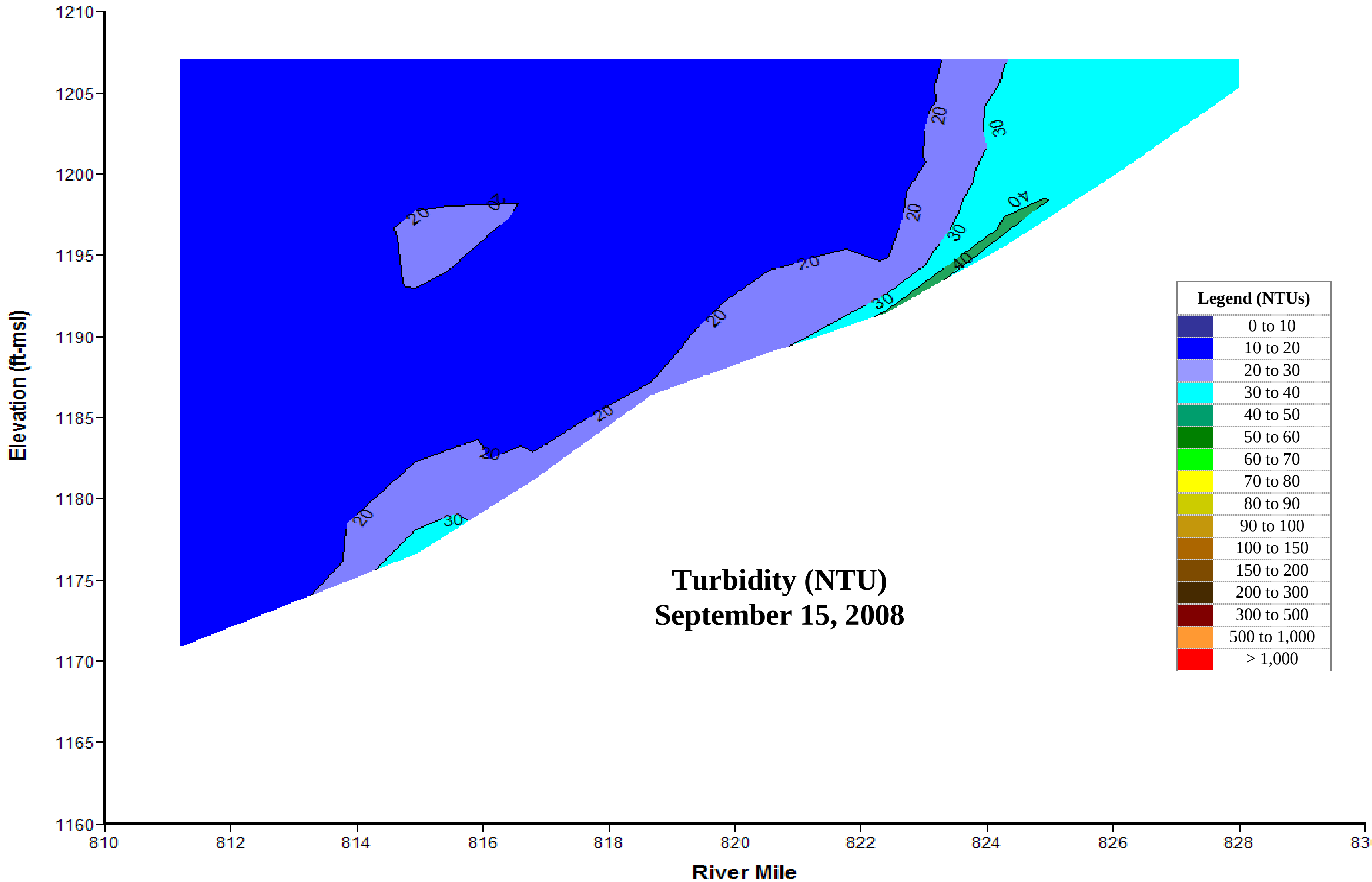

Plate 28. Longitudinal turbidity (NTUs) contour plot of Lewis and Clark Lake based on depth-profile turbidity levels measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on September 15, 2008.

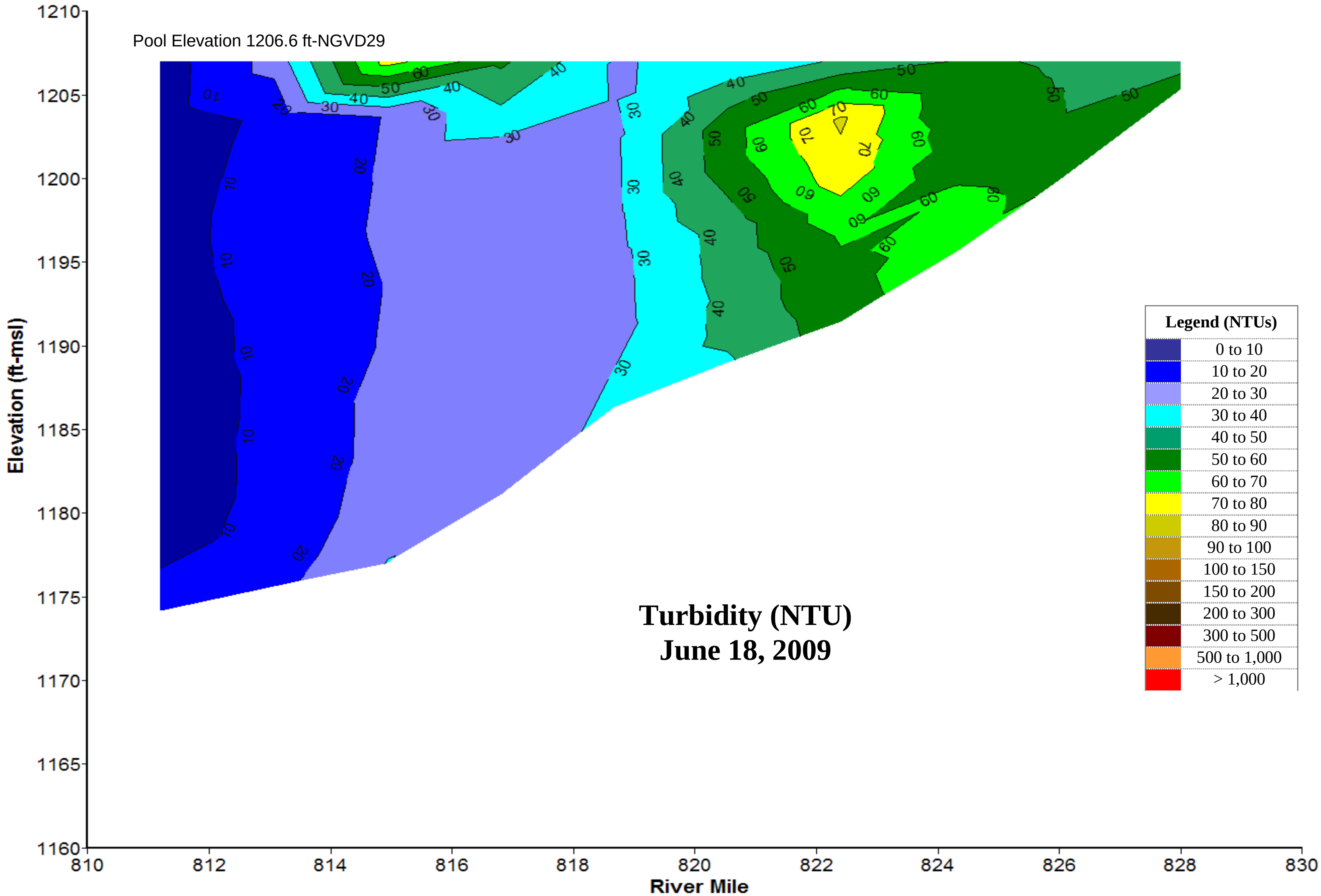

Plate 29. Longitudinal turbidity (NTUs) contour plot of Lewis and Clark Lake based on depth-profile turbidity levels measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on June 18, 2009.

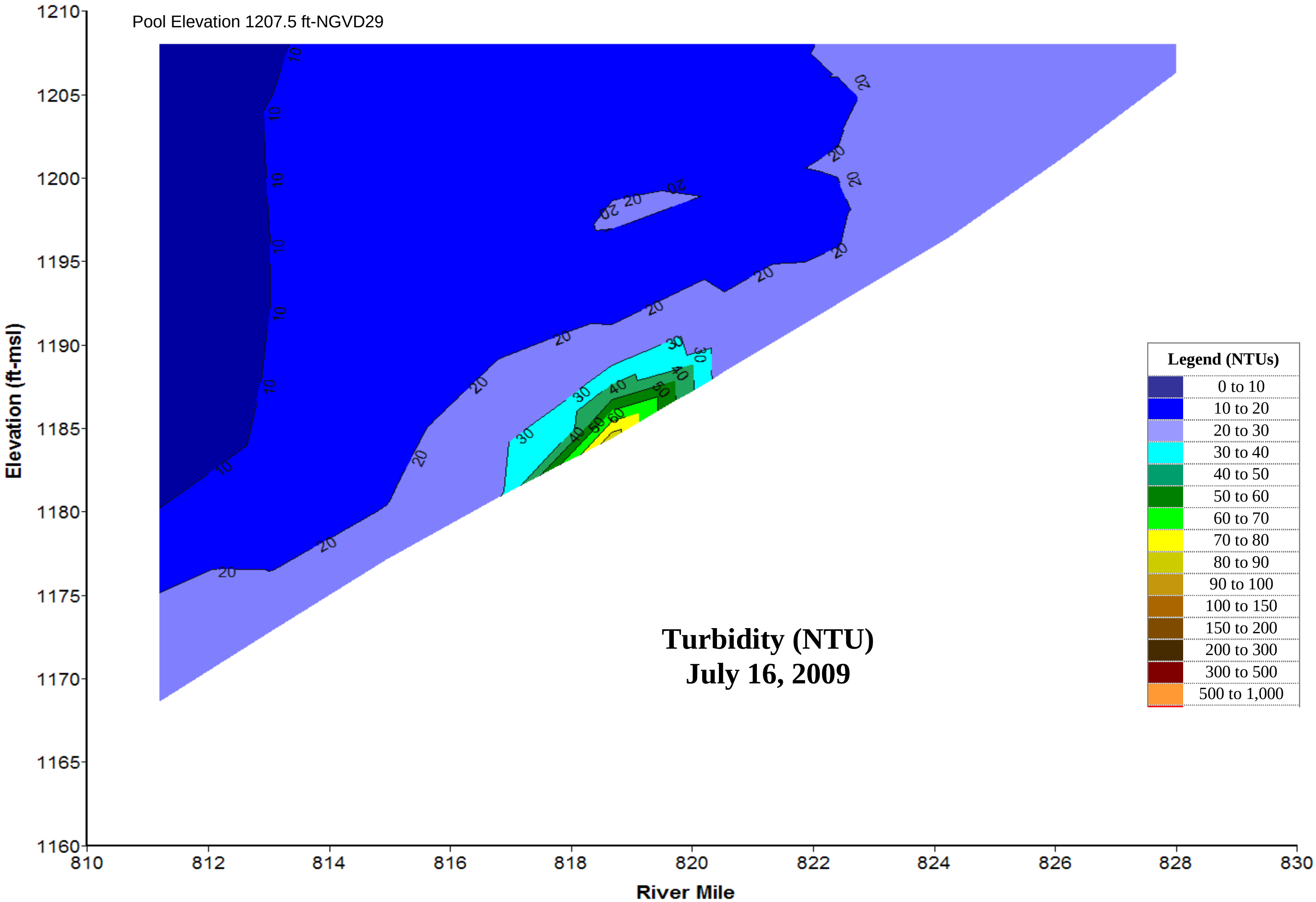

Plate 30. Longitudinal turbidity (NTUs) contour plot of Lewis and Clark Lake based on depth-profile turbidity levels measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on July 16, 2009.

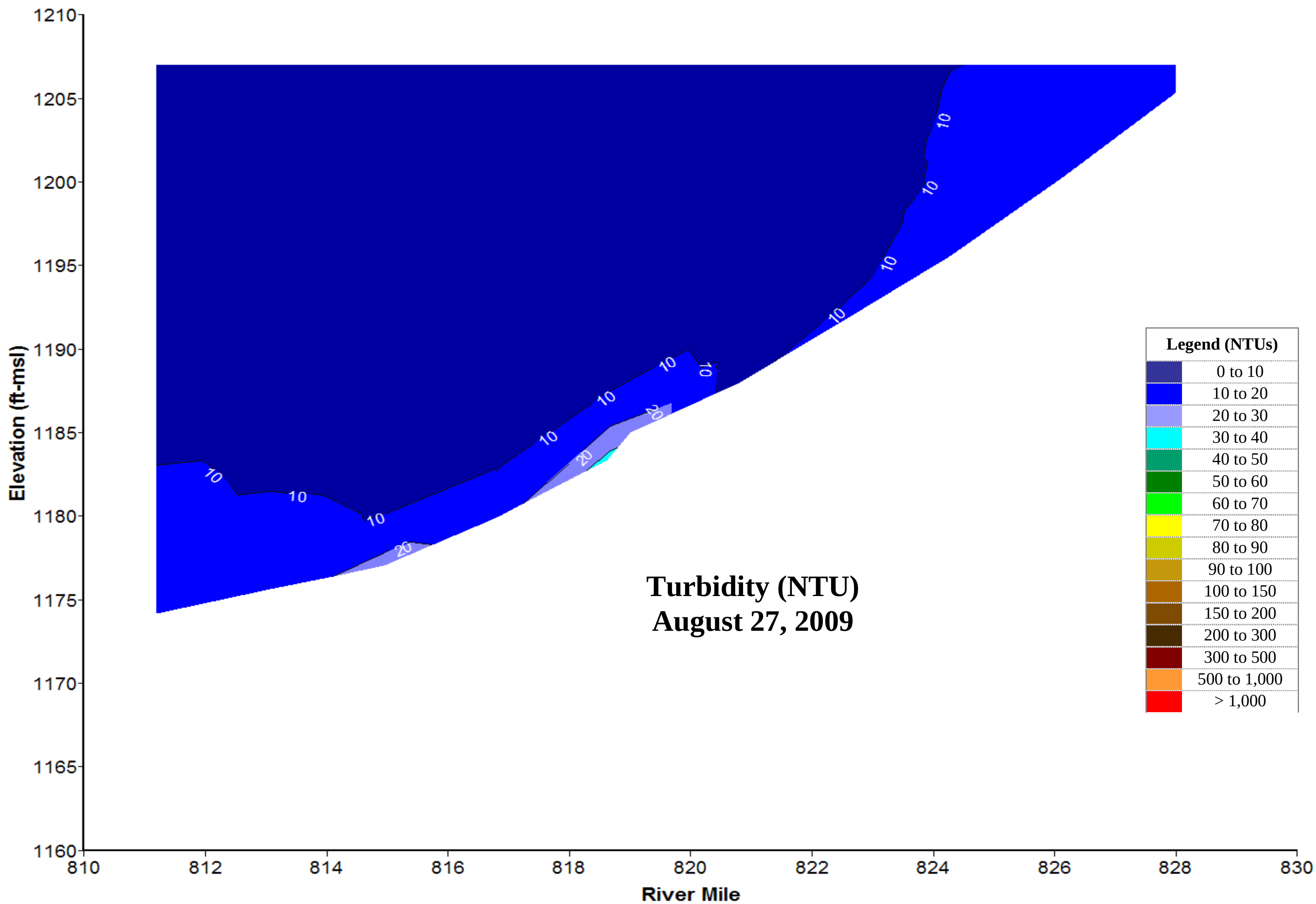

Plate 31. Longitudinal turbidity (NTUs) contour plot of Lewis and Clark Lake based on depth-profile turbidity levels measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on August 27, 2009.

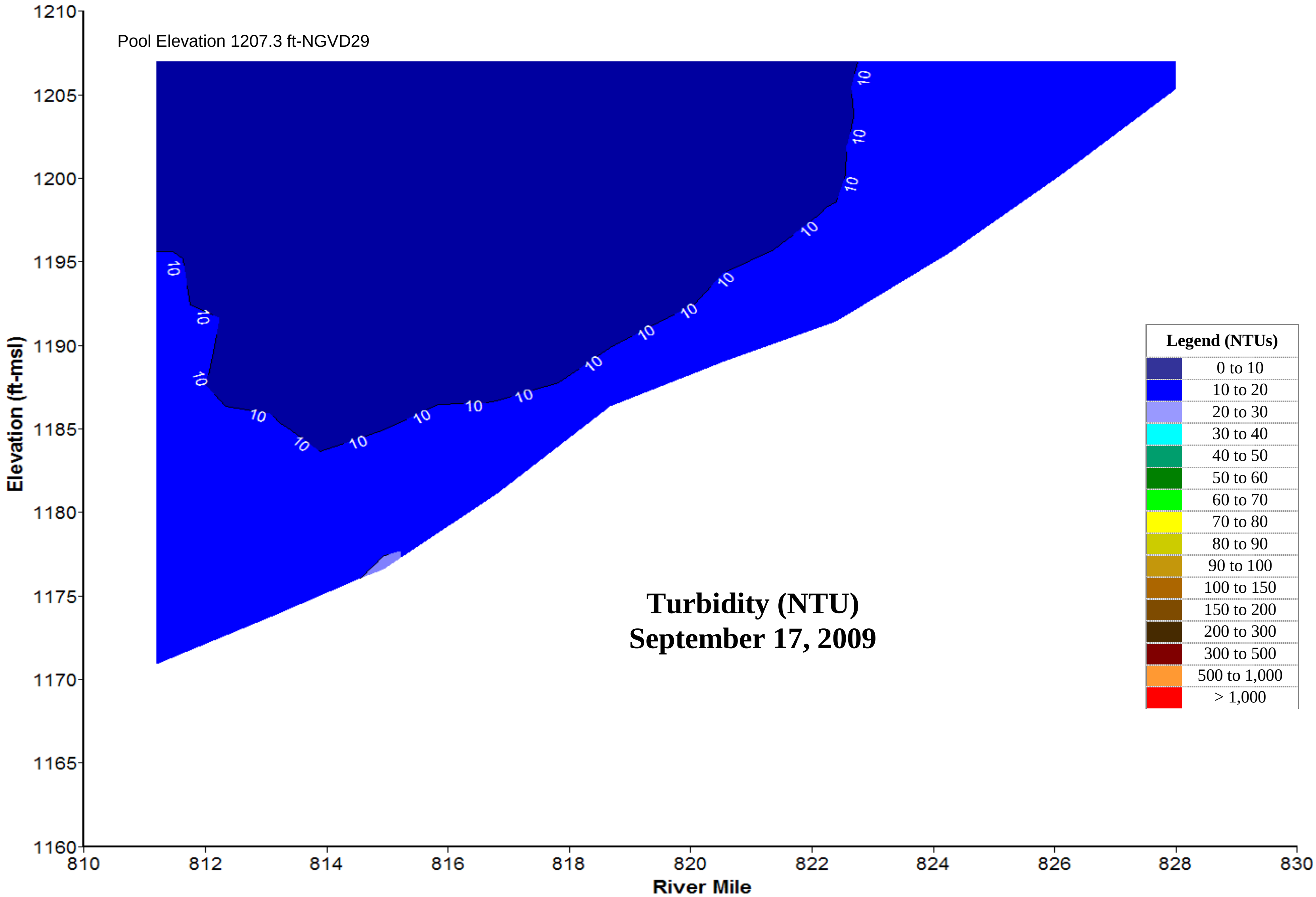

Plate 32. Longitudinal turbidity (NTUs) contour plot of Lewis and Clark Lake based on depth-profile turbidity levels measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on September 17, 2009.

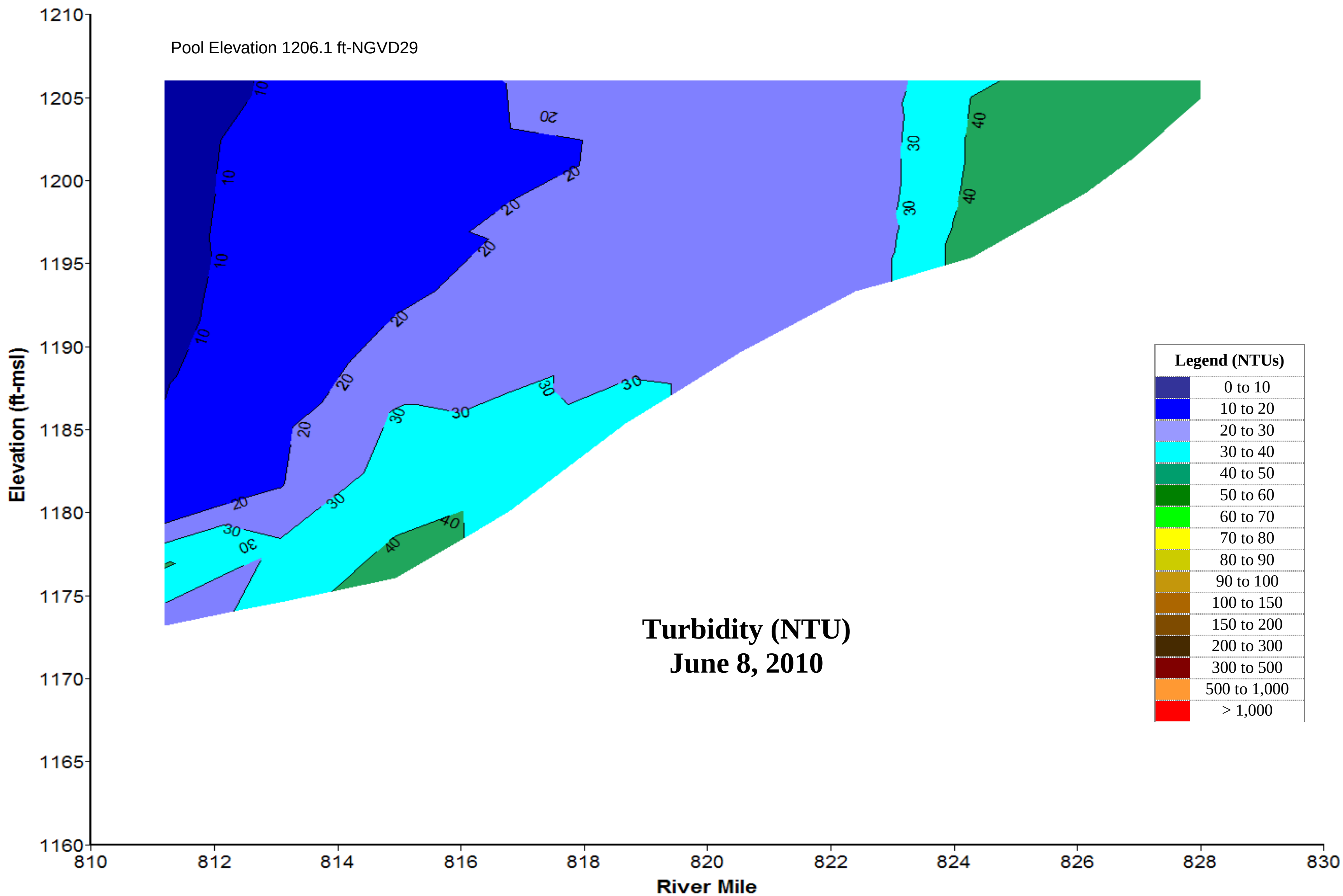

Plate 33. Longitudinal turbidity (NTUs) contour plot of Lewis and Clark Lake based on depth-profile turbidity levels measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on June 8, 2010.

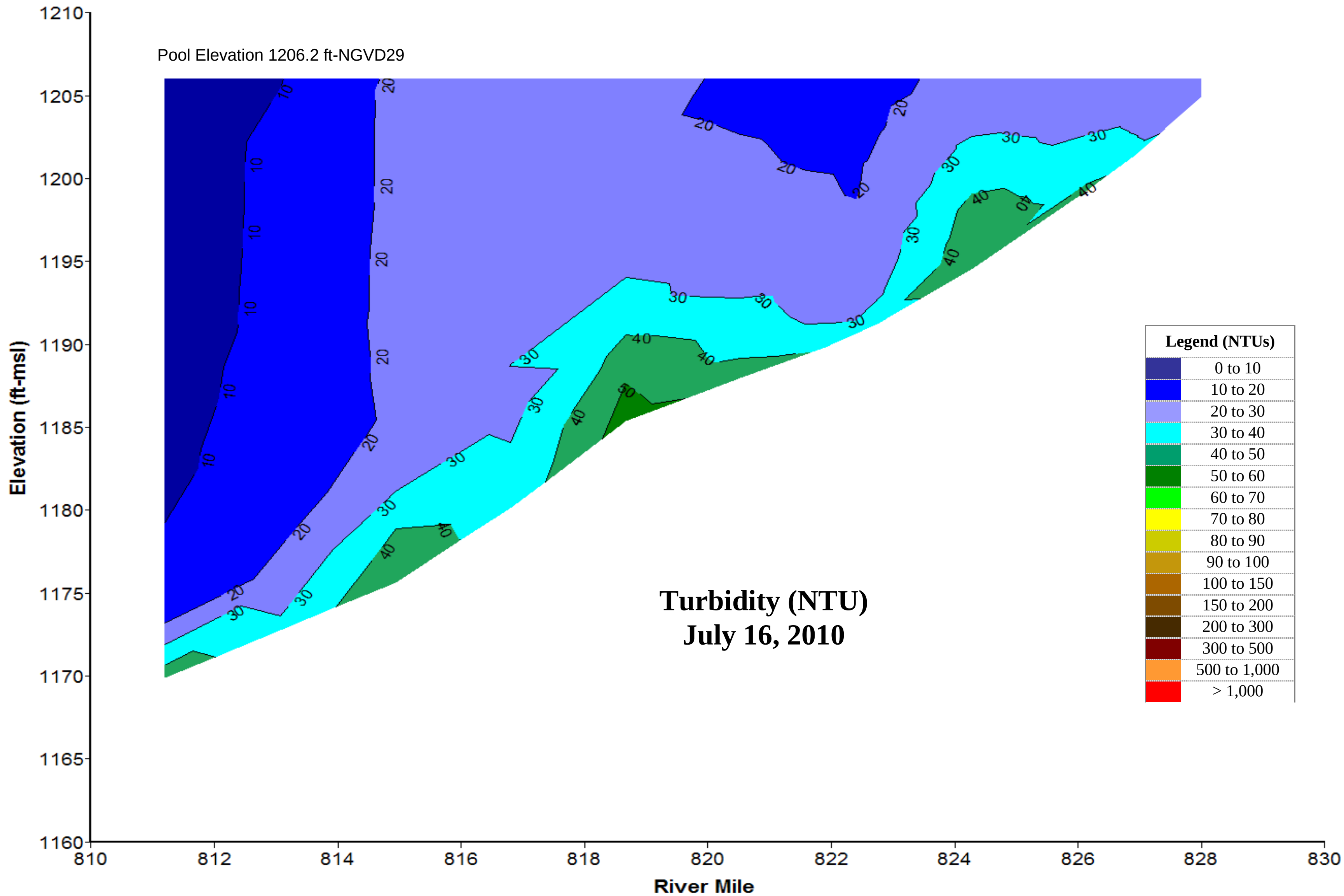

Plate 34. Longitudinal turbidity (NTUs) contour plot of Lewis and Clark Lake based on depth-profile turbidity levels measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on July 16, 2010.

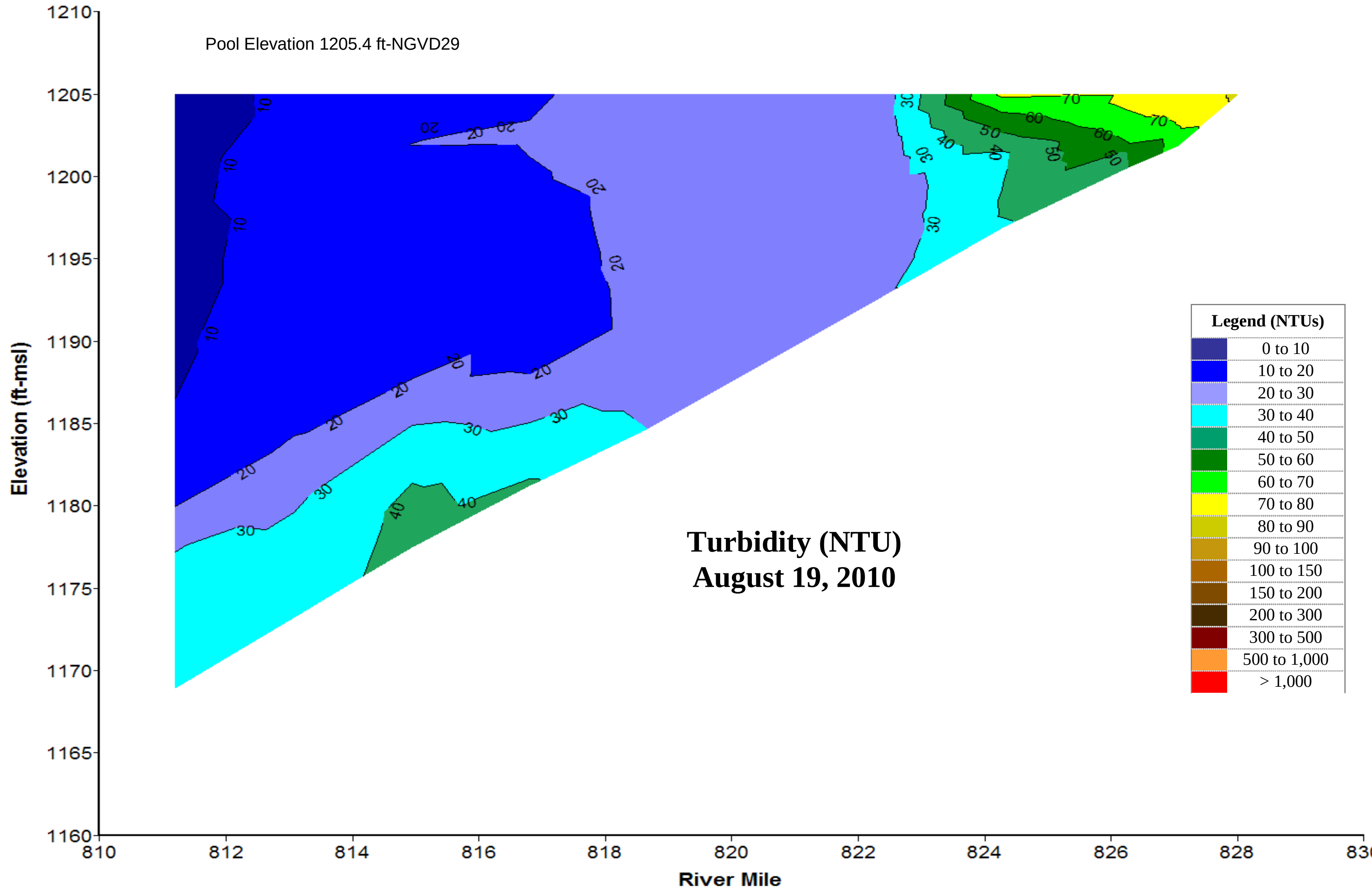

Plate 35. Longitudinal turbidity (NTUs) contour plot of Lewis and Clark Lake based on depth-profile turbidity levels measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on August 19, 2010.

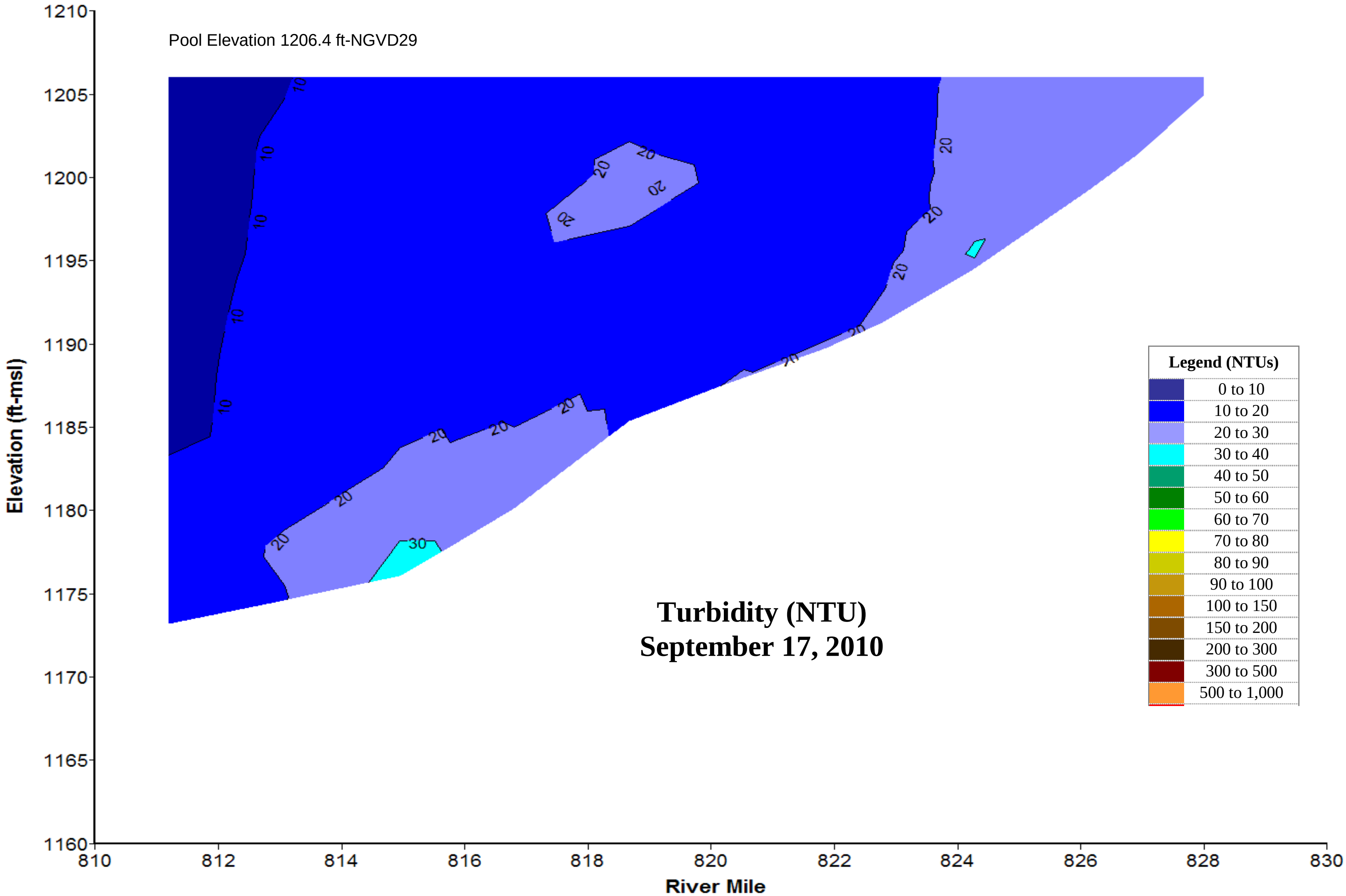

Plate 36. Longitudinal turbidity (NTUs) contour plot of Lewis and Clark Lake based on depth-profile turbidity levels measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on September 17, 2010.

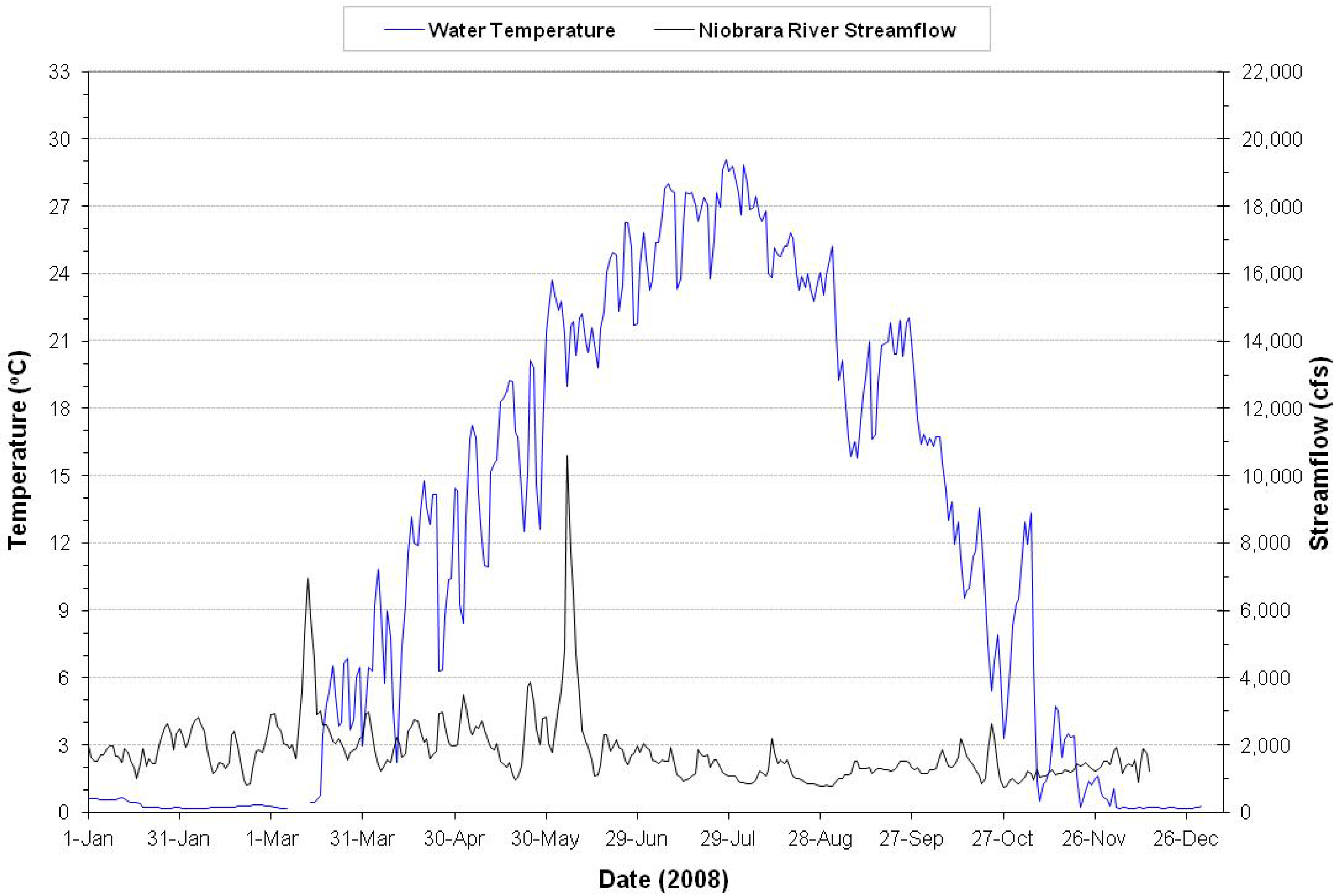

Plate 37. Mean daily water temperature and streamflow of the Niobrara River near Verdel, Nebraska (i.e., site USGS 06465500) for 2008.

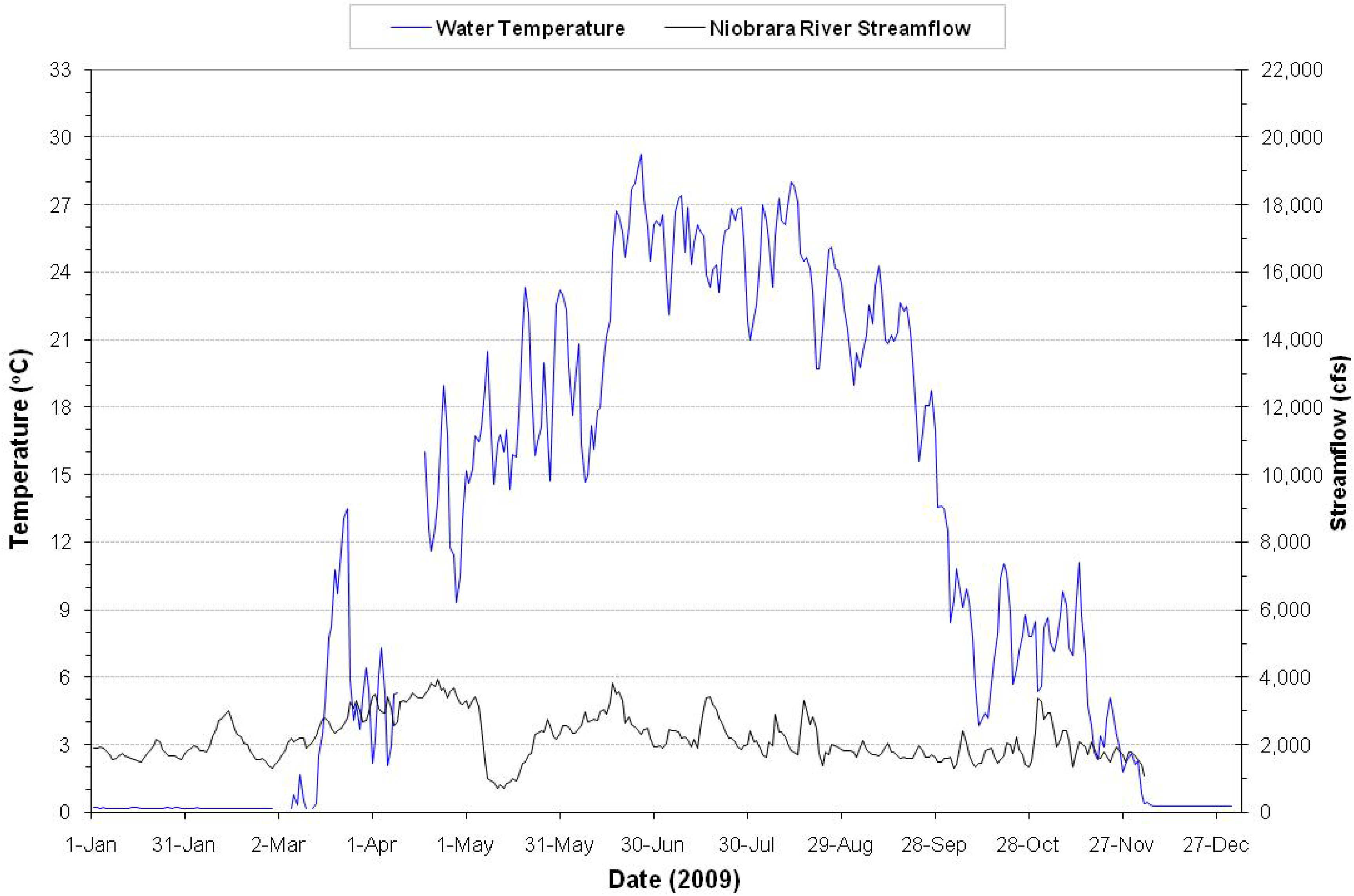

Plate 38. Mean daily water temperature and streamflow of the Niobrara River near Verdel, Nebraska (i.e., site USGS 06465500) for 2009.

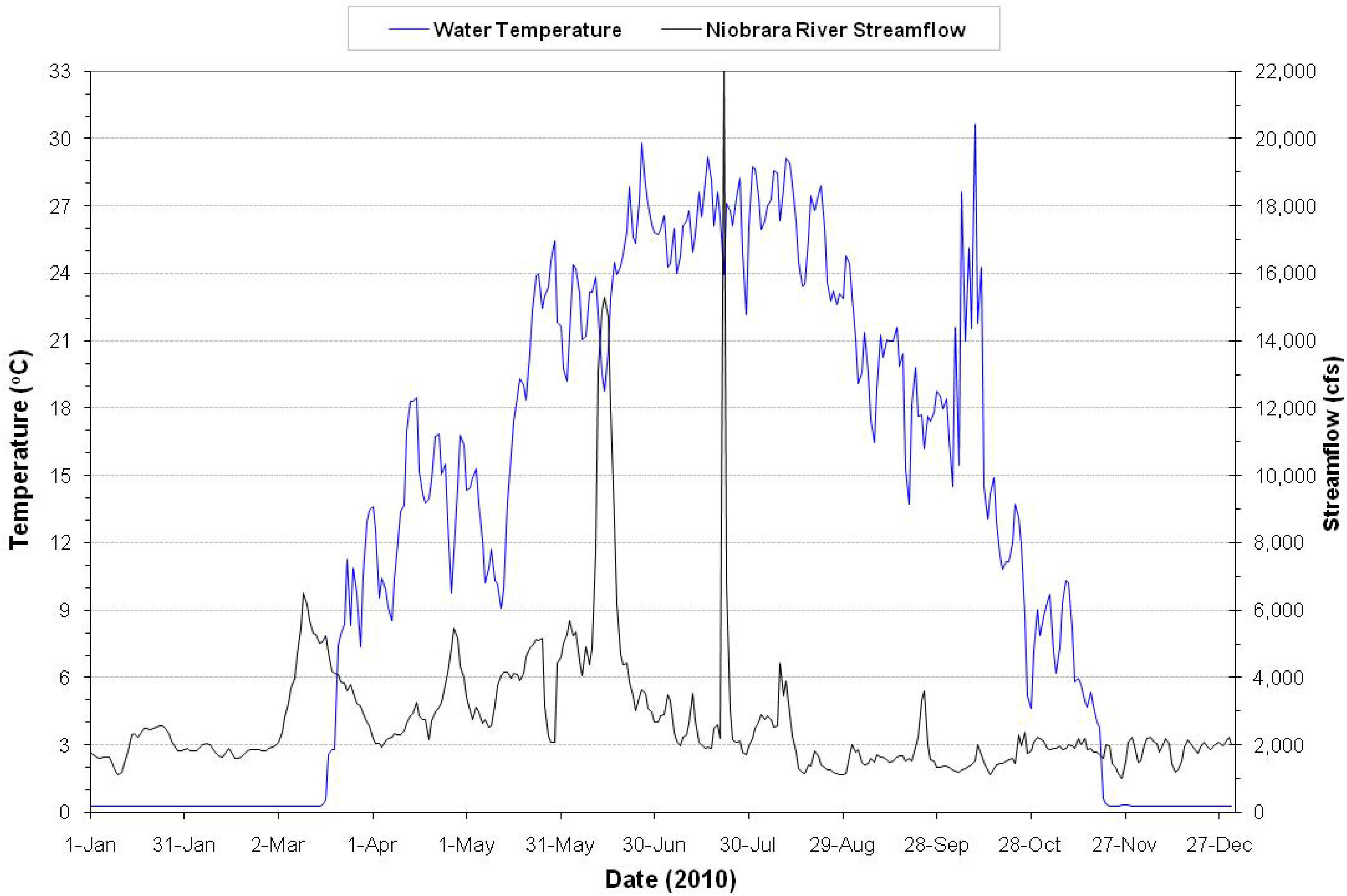

Plate 39. Mean daily water temperature and streamflow of the Niobrara River near Verdel, Nebraska (i.e., site USGS 06465500) for 2010.

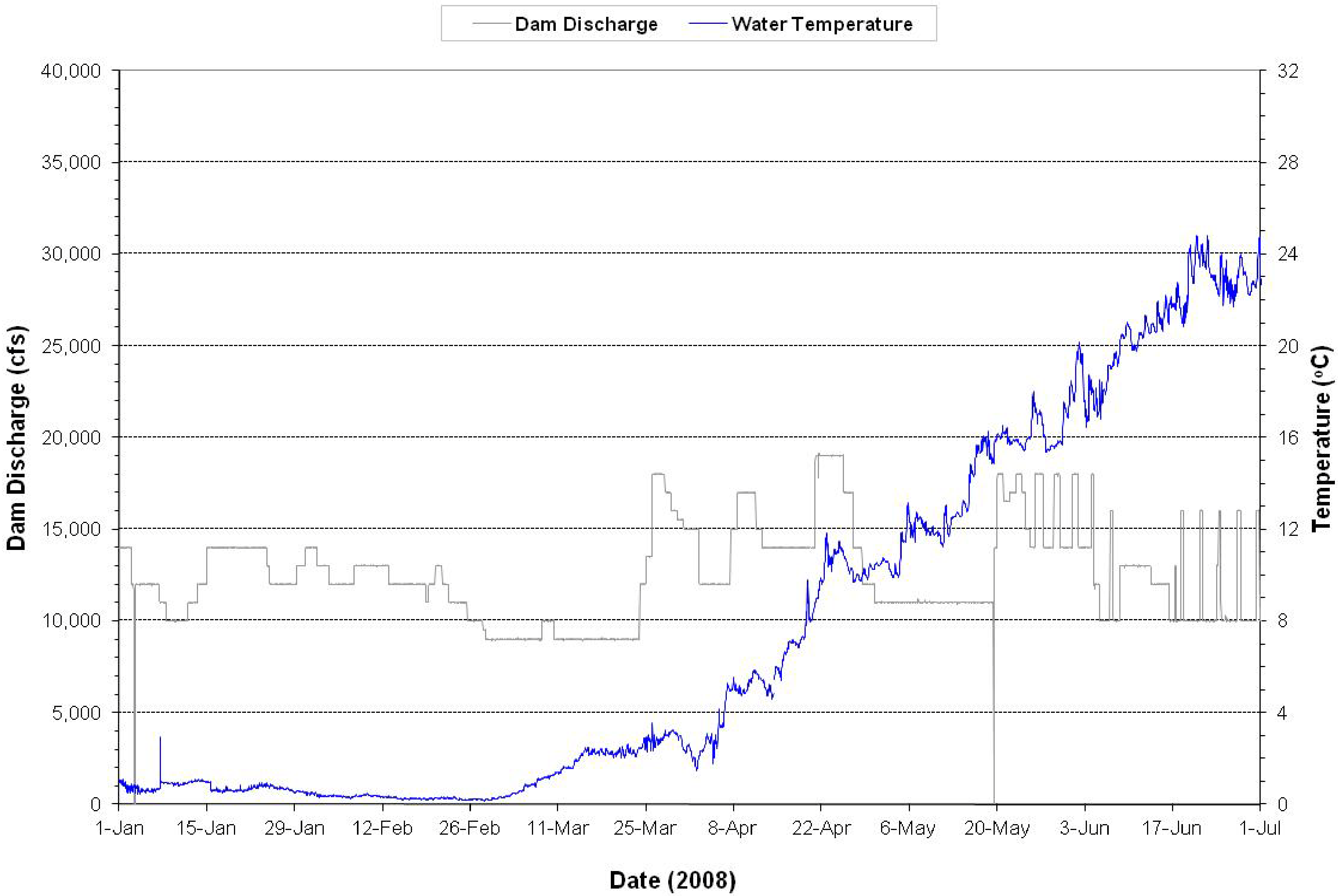

Plate 40. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the dam during the period January through June 2008.

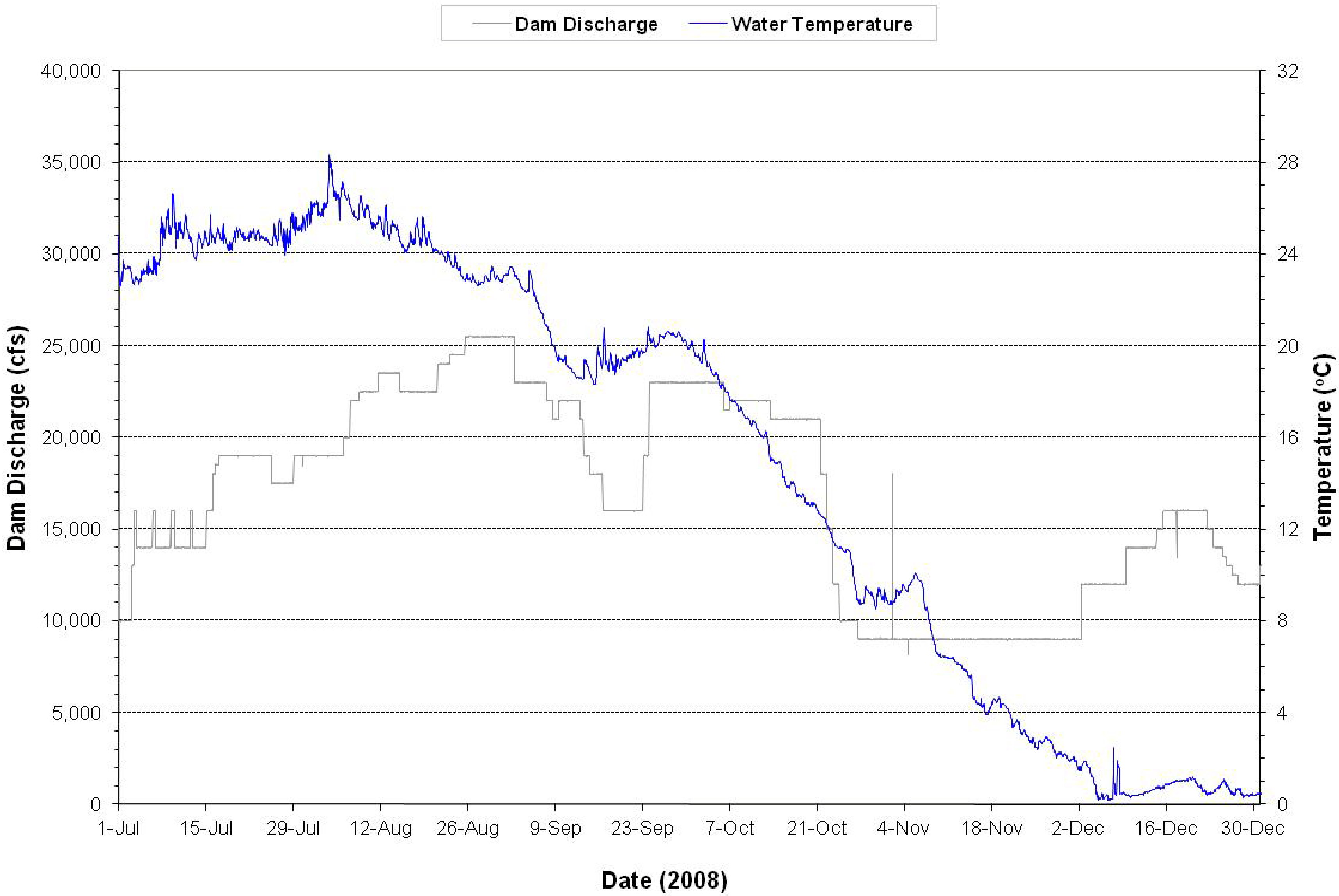

Plate 41. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the dam during the period July through December 2008.

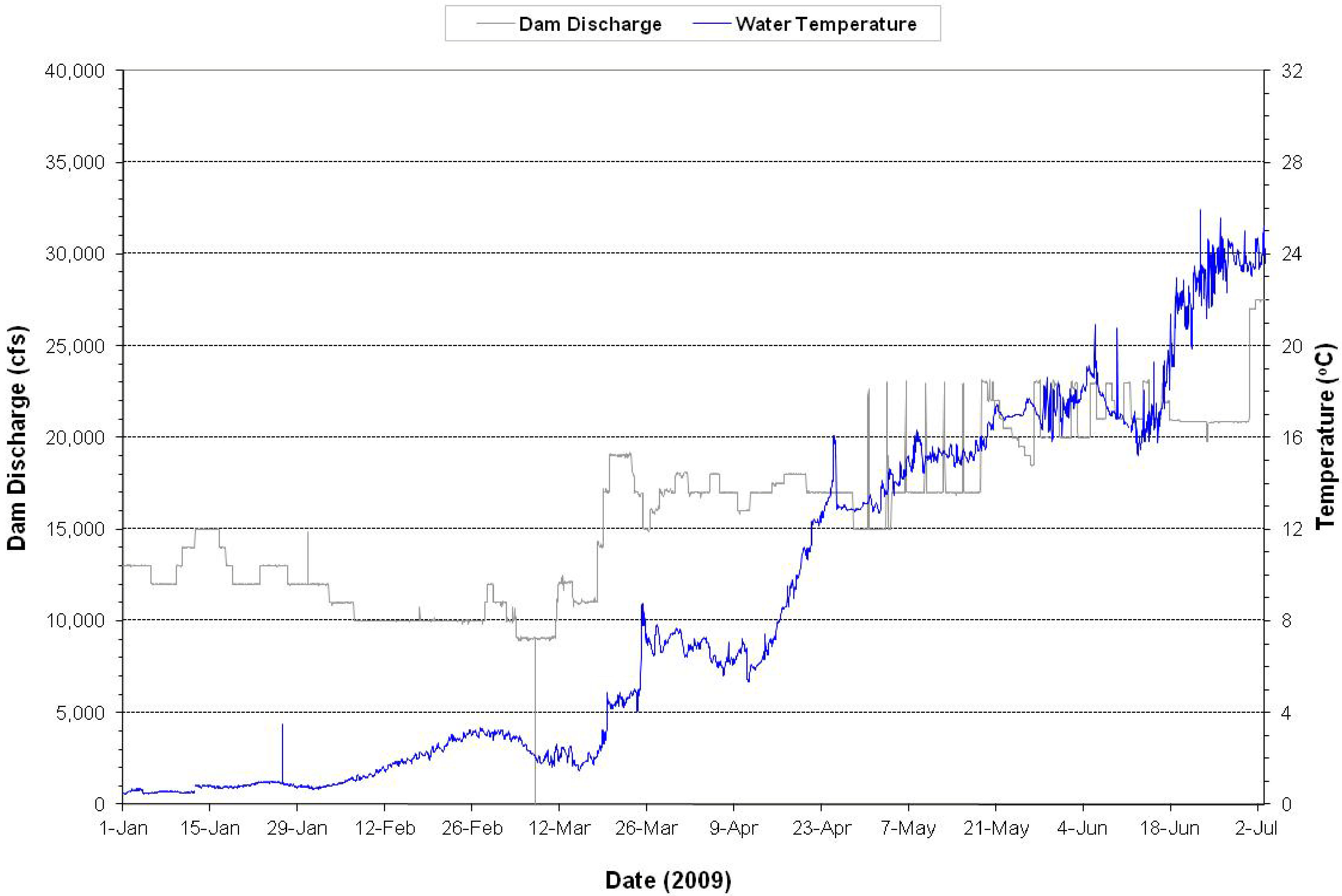

Plate 42. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the dam during the period January through June 2009.

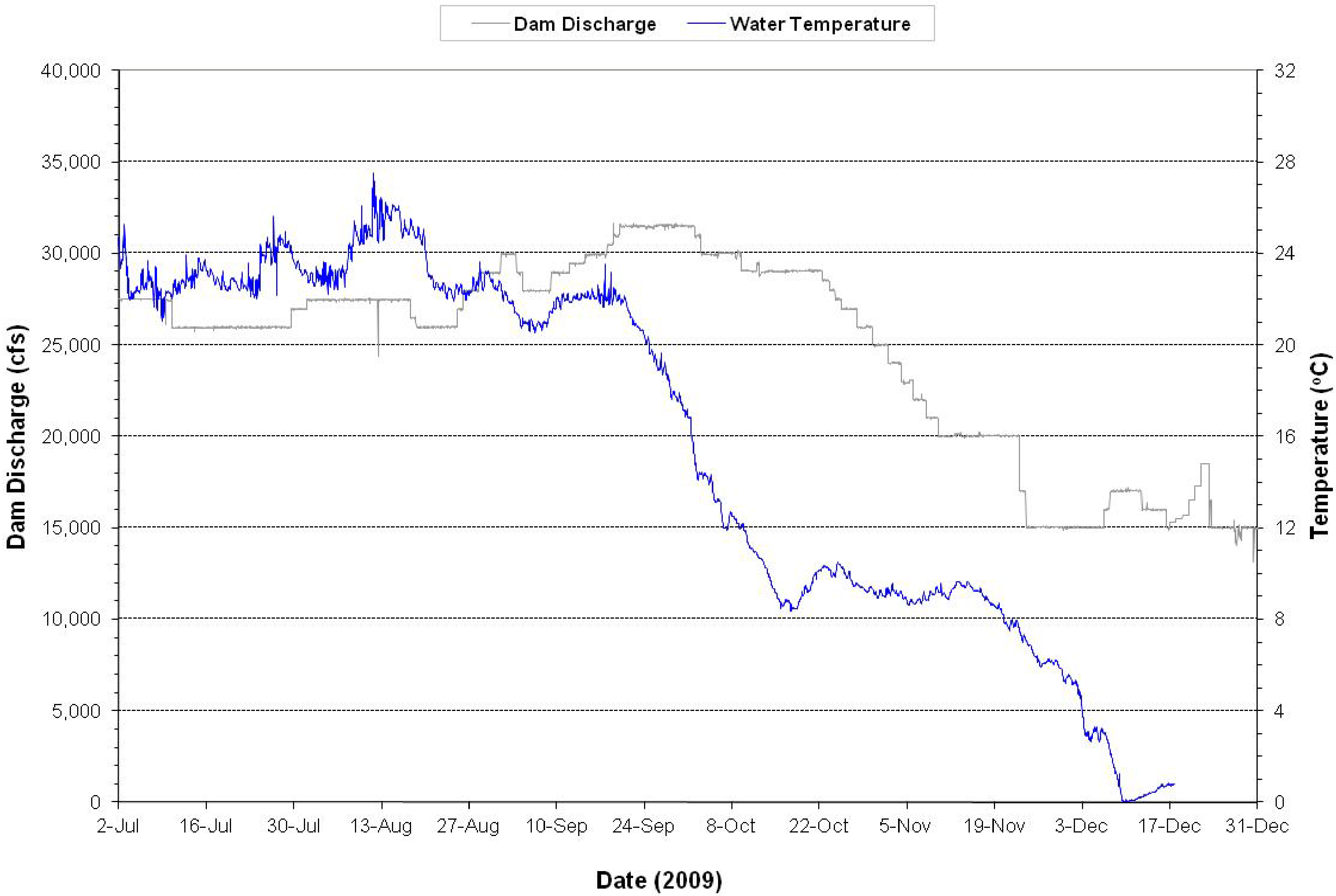

Plate 43. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the dam during the period July through December 2009.

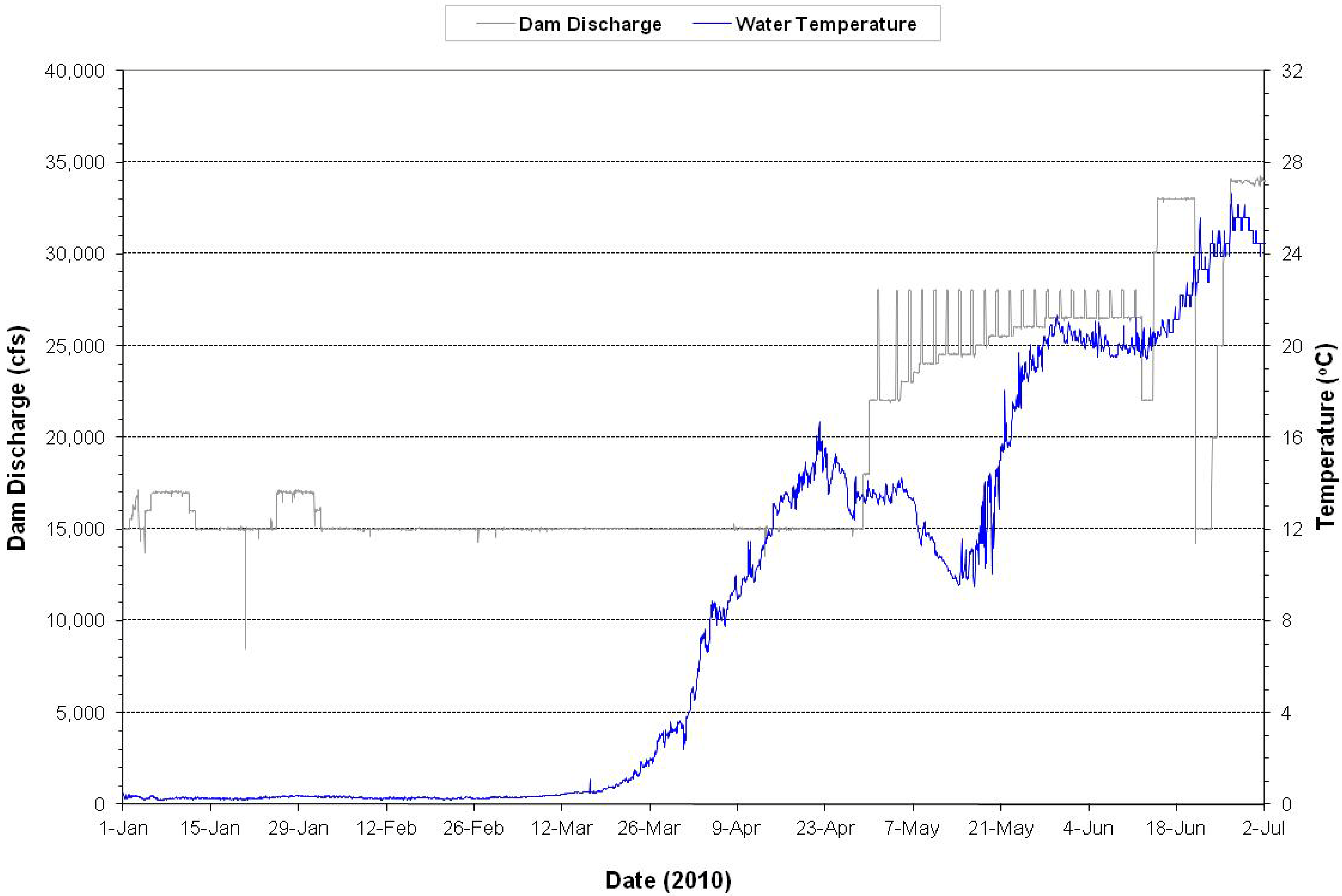

Plate 44. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the dam during the period January through June 2010.

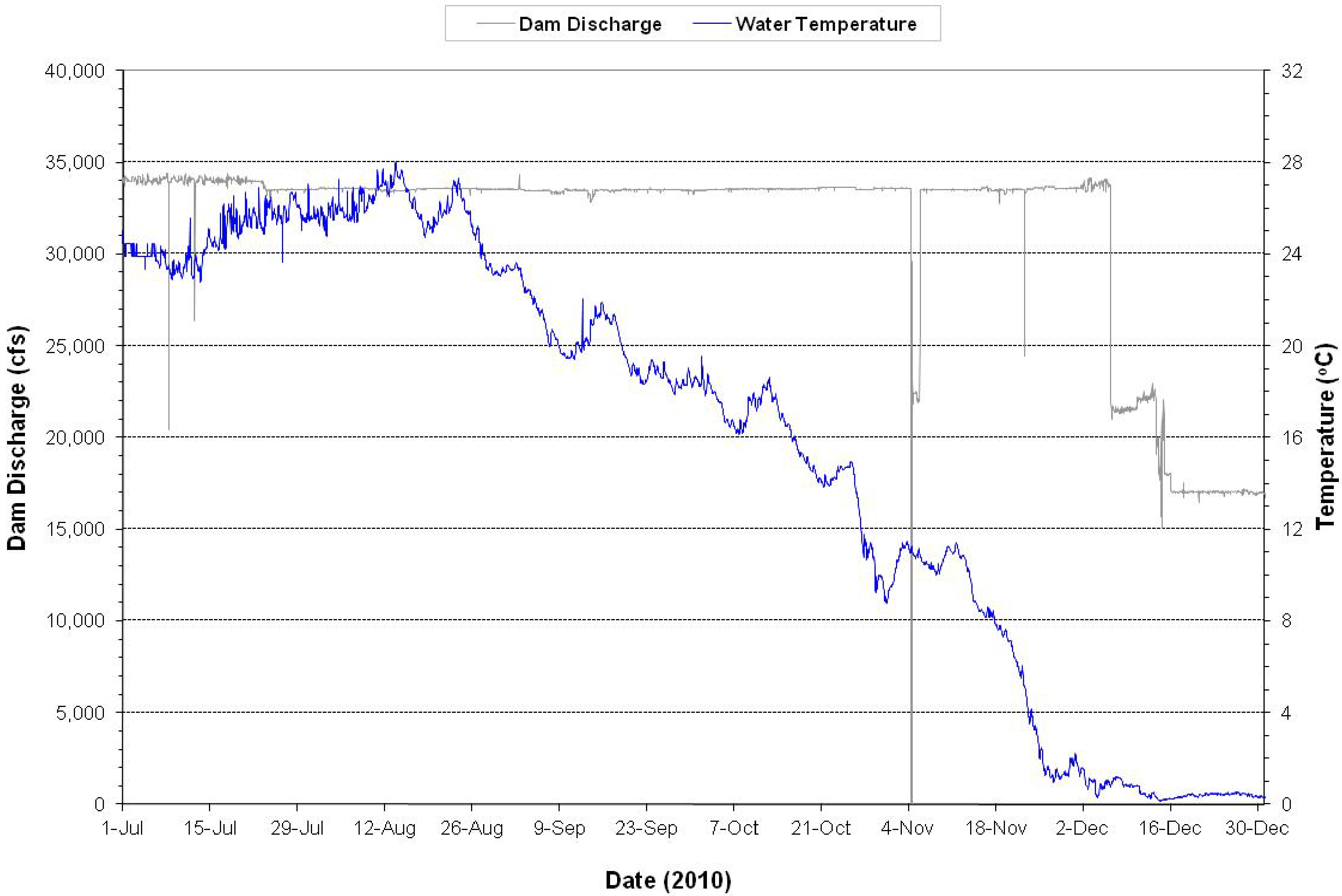

Plate 45. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the dam during the period July through December 2010.

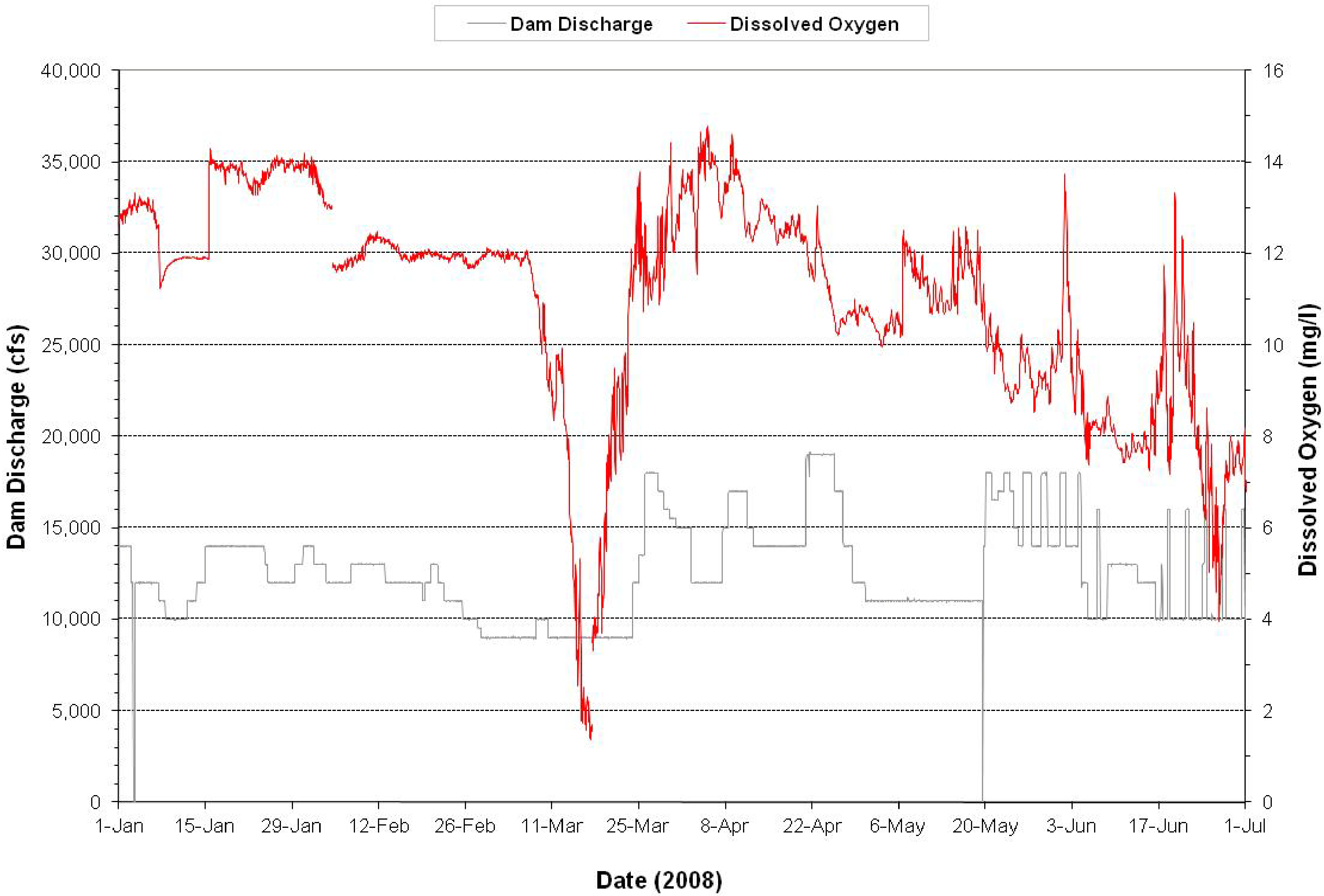

Plate 46. Hourly discharge and dissolved oxygen concentrations monitored at the Gavins Point powerplant on water discharged through the dam during the period January through July 2008.

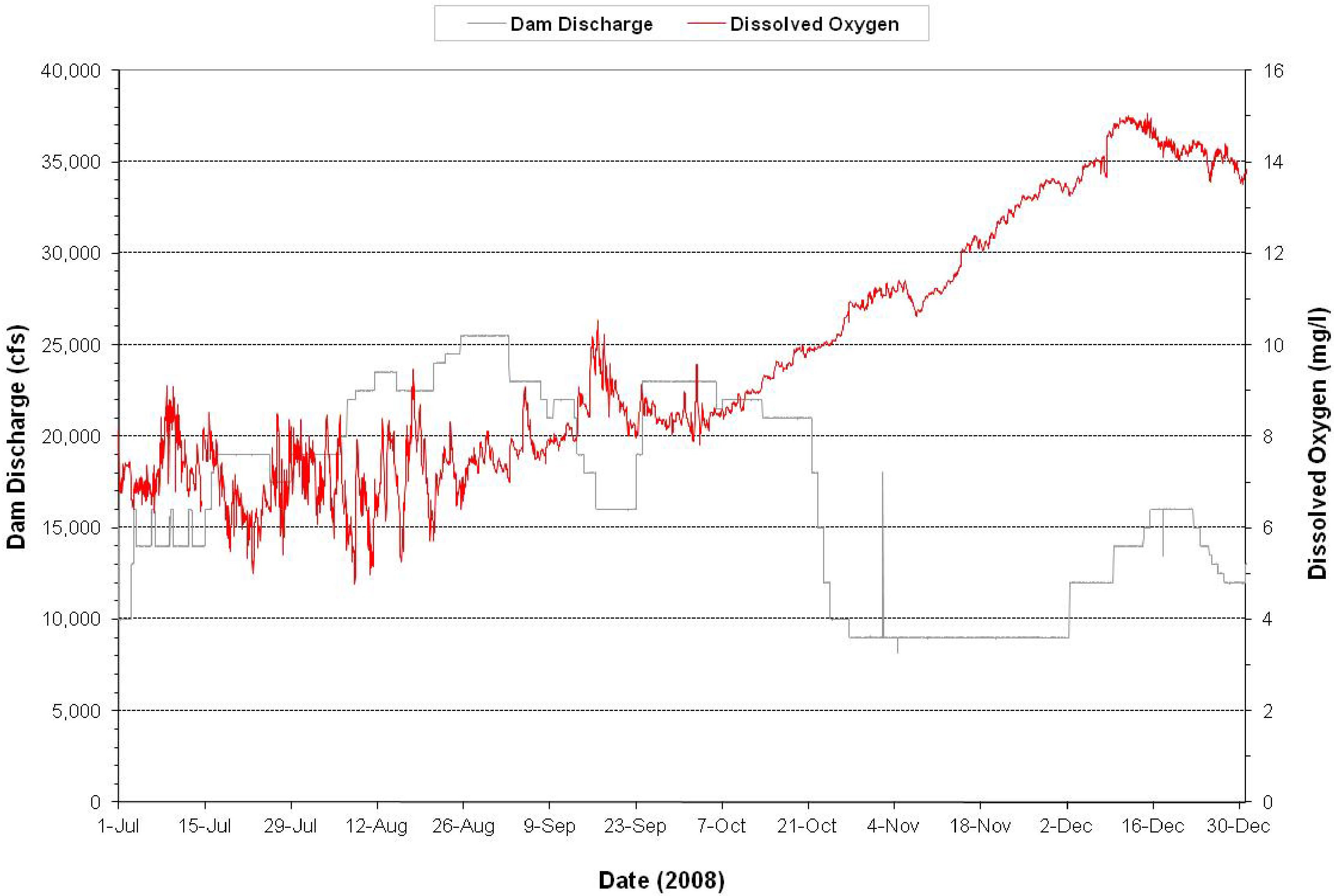

Plate 47. Hourly discharge and dissolved oxygen concentrations monitored at the Gavins Point powerplant on water discharged through the dam during the period July through December 2008.

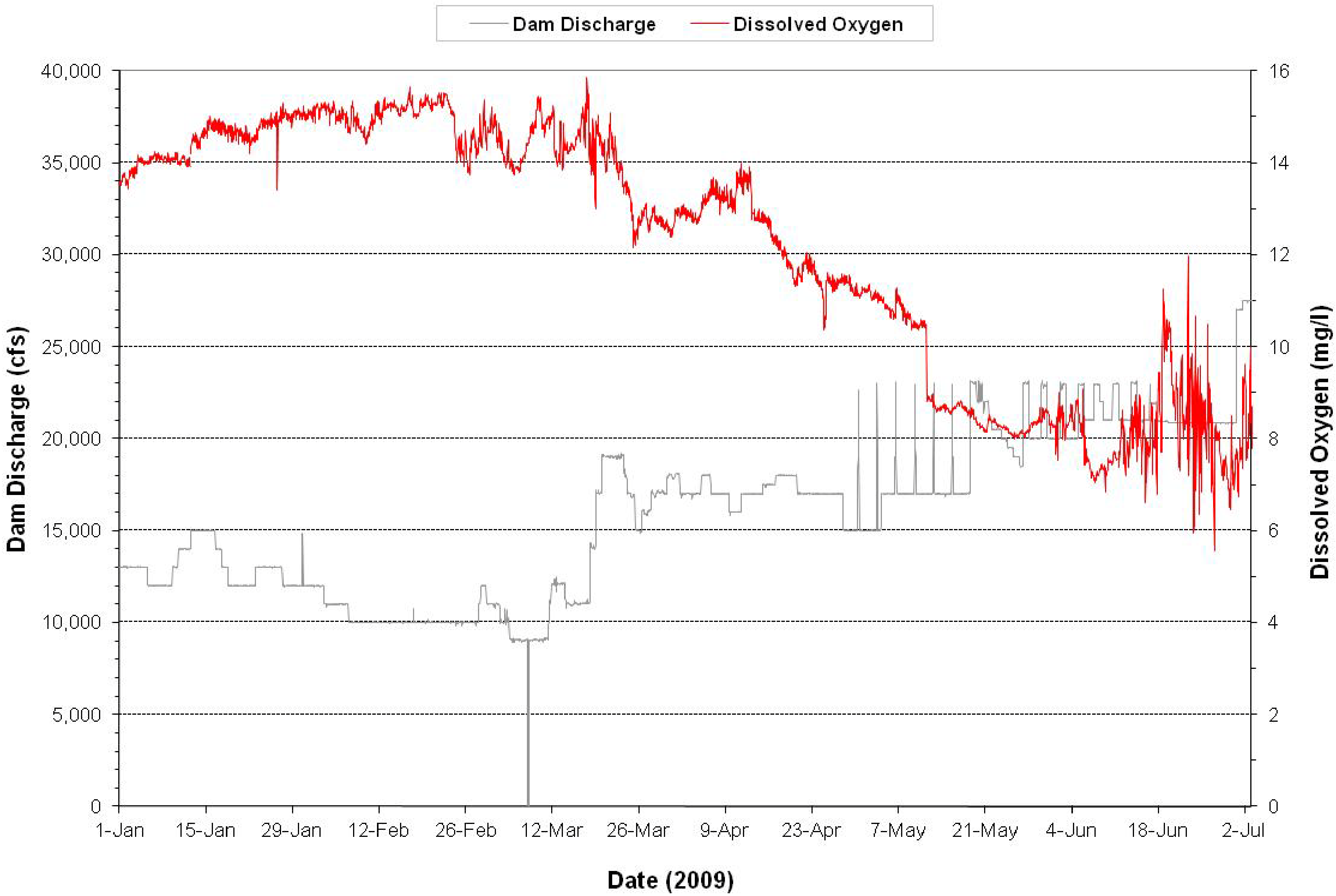

Plate 48. Hourly discharge and dissolved oxygen concentrations monitored at the Gavins Point powerplant on water discharged through the dam during the period January through July 2009.

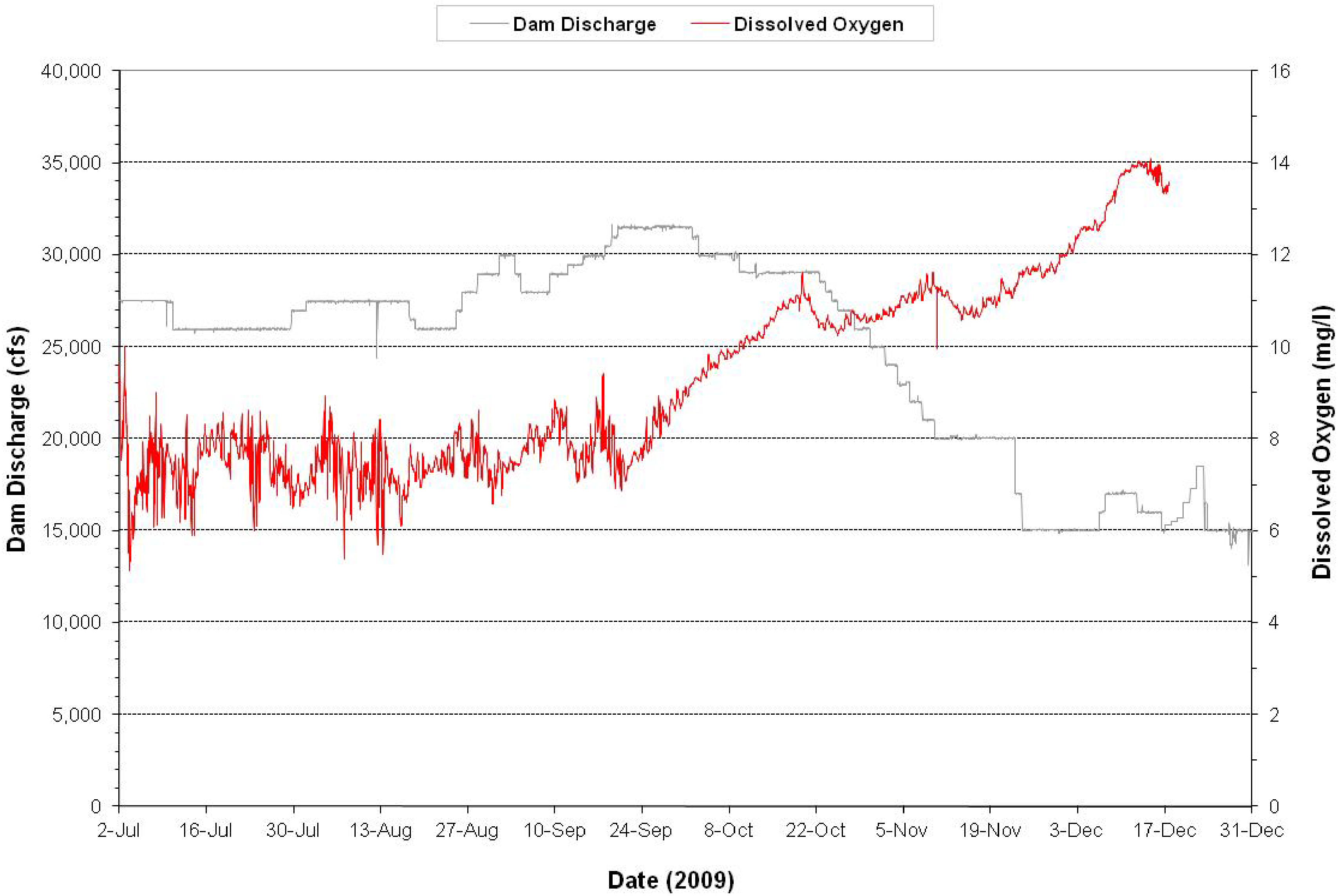

Plate 49. Hourly discharge and dissolved oxygen concentrations monitored at the Gavins Point powerplant on water discharged through the dam during the period July through December 2009.

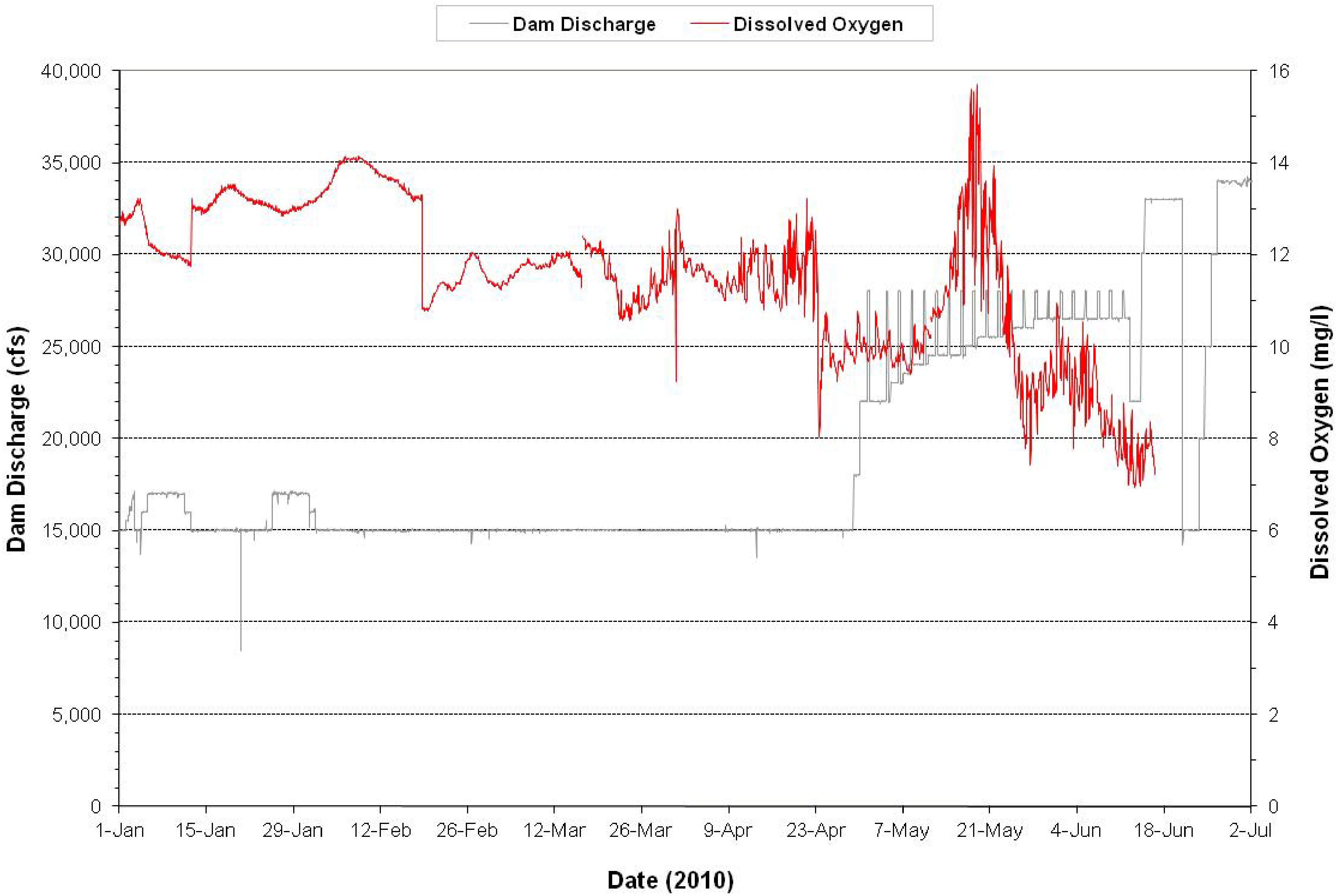

Plate 50. Hourly discharge and dissolved oxygen concentrations monitored at the Gavins Point powerplant on water discharged through the dam during the period January through July 2010.

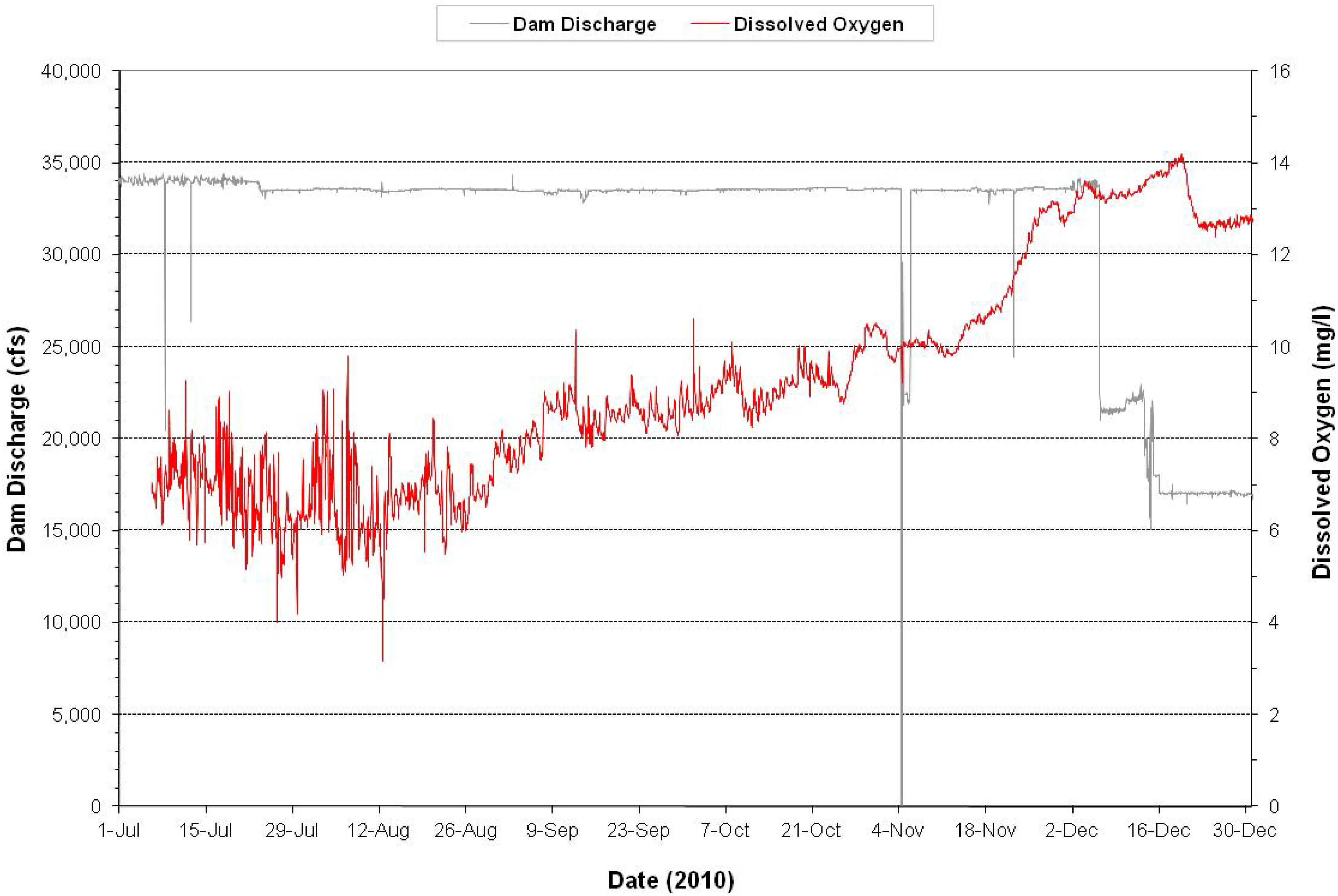

Plate 51. Hourly discharge and dissolved oxygen concentrations monitored at the Gavins Point powerplant on water discharged through the dam during the period July through December 2010.